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PALYNOLOGY OF LATE CRETACEOUS MAMMAL-BEDS, SCOLLARD, ALBERTA

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY

by

S. K. SRIVASTAVA, B.Sc.

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UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Palynology of Late Cretaceous Mammal-beds, Scollard, Alberta", submitted by S. K. Srivastava, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Fossil mammal bones have been located in Upper Cretaceous (Lance or Maestrichtian) Upper Edmonton beds above the Kneehills Tuff in the Scollard area, Alberta. Samples from the mammal bearing beds and from above and below, have been analysed for their palynological contents. One hundred species belonging to 57 genera of spores and pollen grains have been identified and described. Relations with the Recent flora indicate the presence of the following families:

Sphagnaceae, Cyatheaceae, Gleicheniaceae, Osmundaceae, Lycopodiaceae, Schizaeaceae, Salviniaceae, Polypodiaceae, Cycadaceae, Taxodiaceae, Cupressaceae, Podocarpaceae, Pinaceae, Urticaceae, Betulaceae, Myricaceae, Proteaceae, Rhizophoraceae, Anacardiaceae, Salicaceae, Aquifoliaceae, Oleaceae, Myrtaceae, Fagaceae, Juglandaceae, Ericaceae, Magnoliaceae, Liliaceae, Loranthaceae, Restionaceae, Platanaceae, Santalaceae, Lythraceae.

Five broad paleoecological breaks could be delineated based on microfloral assemblages. Microfloral Assemblage I, II and III were collected below the Kneehills Tuff and IV and V above it. The lowest Microfloral Assemblage I representing mid Middle Edmonton vegetation indicates swampy, tropical and humid climate which was replaced by stages of a sere of cooler climate shown by Microfloral Assemblage II. Cooling increased still more, possibly due to decrease in the total solar radiation reaching the earth's surface, caused by the volcanic dust in the atmosphere as the bentonitic content is high. Microfloral Assemblage III from the bentonitic beds associated with the Kneehills Tuff shows no preservation of spores and pollen although comminuted fragments are present. Microfloral Assemblage IV, (including the mammal beds) shows warming up and restoration of recognisable vegetation but of a cooler climate. Climate became warmer during the deposition of Microfloral Assemblage V and a rich woodland vegetation was established representing warm subtropical climate with warm temperate aspect during mid Upper Edmonton deposition.

Mammals in the Upper Edmonton Member appear as a fore-shadowing of the Tertiary fauna in a temporary period of cooling during early Lance time in fluvial to fluvio-deltaic conditions. An erosional unconformity is noted, above the Kneehills Tuff and below the mammal beds, cutting down into the Blackmud beds associated with the Tuff.

ACKNOWLEDGEMENTS

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CHAPTER ONE

INTRODUCTION

Preamble

About 2,500 to 3,000 years ago, Assyrians recognised sex in plants, but not until the late seventeenth century was pollen identified through the early microscopes and described independently by Grew and Malpighi. They termed them 'globes' and 'globulets' (Wodehouse, 1935). Pollen studies remained dormant and of academic nature till the late nineteenth century, being closely associated with the development of microscopy. The value of fossil spores and pollen grains in stratigraphy was indicated by the early workers, Henry Witham in 1833 (Kosanke, 1950) and Morris in 1840 (Bennie and Kidston, 1886), but Lennart von Post is given prime recognition for interpretation of stratigraphy, correlation and ecology by statistical use of pollen in 1916 (Erdtman, 1943).

With the increasing interest in the studies of spores and pollen grains and establishment of its application in the diverse fields of geology, botany, archaeology, pharmacology and aerobiology, it became identified as a disciplined science, and in 1944, Hyde and William proposed the name 'Palynology' for all studies of spores and pollen grains (Srivastava, 1962). Much of the palynological studies done in the first four decades of this century were mainly limited to Quaternary deposits. The recognition of the stratigraphical value of spores and pollen grains and its application to oil finding, placed palynologists in a professional position during the last two decades. Many microfossils, other than spores and pollen grains, are also recovered by using palynological techniques and are useful in correlation, dating, and interpretation of paleoecology. Hoffmeister (1955) included in palynology the studies of such microfossils ranging up to 150 microns. These include microfossils such as algae, fungi, dinoflagellates, hystrichospheres, acritarchs, tintinnids, radiolaria, microforaminifera, nannoconus, chitinozoans, etc. The individual importance of many of these micro-

fossils has been shown by Hoffmeister (1960). Funkhouser (1959), during the Ninth International Botanical Congress held at Montreal, introduced new branches in palynology as I) spore-pollen palynology, II) non-spore-pollen palynology - including algae, fungi, cuticles etc., and III) zoo-palynology - including other microfossils of animal origin.

Limitations of Palynology for Stratigraphy and Paleoecology

Godwin (1934) gave an outline of the problems and methods of pollen analysis and Cain (1939) reviewed early palynological work done and advocated the potentialities of pollen analysis as a paleoecological research method. He summarised the advantages of pollen analysis into six categories viz.

(1) Structural characteristics of pollen grains seem constant for a species.

(2) Most dominant trees of temperate zones are anemophilous, so there is a homogenous mixture of representative pollen deposited.

(3) Pollen are nicely preserved under antiseptic and low oxidation conditions.

(4) With the accumulation of deposits, pollen is also preserved in stratigraphic order.

(5) Pollen is abundant in deposits, and by proper sampling and preparation, their detection, identification and counting is easy.

(6) Pollen spectra based on percentage composition gives stratigraphic-time-vegetation-climate correlation.

Although the pollen grains usually show definite and established characteristics for particular species, genera and families, instances are frequent where different species, genera and families are represented by pollen grains with similar morphological features. However, pollen grains with different morphological features may sometimes appear within the same species, genera and families. Many eurypalynous families have been noted by Erdtman (1943, 1952). Instances of dimorphism and trimorphism within a

species are also known. Srivastava (1957) noted within some species of Cassia many grains in syncolpate condition, while in others, colpi were free. Still in others, colpi had united at one pole and were free on the other. If these are recovered in the fossil state, it would seem logical to put them into different species at least. In Nothofagus, the number of colpi within one species may vary sometimes from 5 to 9 (Erdtman, 1943, 1952). Srivastava (1961) also recorded abnormal bi-, tri-, and tetra-saccate pollen grains in Pinus roxburghii Sarg.

The difference in buoyancy of pollen grains in the air, wind currents, hygroscopic nature of pollen, and quantity of pollen production by individual species have all greatly influenced the pollen spectra recovered from strata. Erdtman (1943) has noted great diversity of pollen production of individual species. For example the total pollen output of Pinus silvestris is calculated to be 12,500 million, whereas that of Fagus silvatica is 2,050 million, i.e. an approximate ratio of 6:1. Settling ratios in air also vary for different pollen. Ragweed pollen settles out in air at the ratio of 26 to 6 compared with Alternaria spore (Durham, 1944). Hyde (1950) observed the effect of distance from the source, and Muller (1959) has shown that there is an increase in the ratio of small to large pollen grains as one goes seaward.

A good quantity of preserved spores and pollen grains has been found in marine, brackish and fresh water shales, limestones, clays and muds as well as peats, bogs, coal and lignites. The degree of preservation differs in genera and species and many may be under-represented. Sangster and Dale (1961) showed that there is considerable variability in preservation of pollen under identical conditions. Populus is one of the glaring examples in Canada. Fossil Populus leaves have been recorded at various localities from Paleocene deposits (Bell, 1949), but no fossil pollen grains have been recorded yet (Erdtman, 1943). Sangster and Dale (1964) have studied pollen grain preservation of under-represented species in fossil spectra in different depositional conditions and found that Acer was severely degraded and becomes unrecognizable in pond sediments. Pollen is preserved better under anaerobic conditions.

Statistical representation of the occurrence of spores and pollen grains is used by palynologists. No factor may be considered constant, such as dissemination, deposition, preservation, collection of samples, until the slides are actually prepared and counts made. Various attempts have been made to control the collecting, preparation of slides and counting methods, but the quantity, behaviour of grains, and deposition and preservation of individual types of spores and pollen grains are little studied. Davis and Goodlett (1960) compared the present vegetation with the pollen spectra in surface samples from Brownington Pond, Vermont, and found little relation between the frequencies of pollen type and the frequencies of species in the vegetation. They are of the view that the complexion of the past vegetation cannot be deduced accurately from fossil pollen spectra until the relations between the present pollen rain and present vegetation are better understood. They suggest greater knowledge of at least four variables for establishing the relation between vegetation and pollen spectrum, viz., amounts of pollen produced by different species; pollen transport distances; preservation and patterns of deposition of pollen types; local variations in species distributions. Martin and Gray (1962) also emphasized the relation between vegetation and pollen rain. Davis (1963) suggested corrections in pollen spectra through the known ratios of the pollen percentage in recent sediments and percentage of a species in a vegetation, but this is not possible with fossils where the species is not extant. Gray and Guennel (1961) have noted that the relative abundance of spores and pollen grains is a powerful criterion for stratigraphic identification of coal beds of Pennsylvanian age in Indiana, and they have tested the precision of the method by statistical means.

Jeletzky (1965) in discussing the quantifying of biochronological correlation is of the opposite view:

> "All statistical methods used in biochronological (=biostratigraphical) correlation depend on the assumption that all taxa in faunal samples compared are statistical units (numbers) either equal or comparable to each other in their biochronological value. However, this assumption is erroneous ......

It is impossible to express the degree of biochronological usefulness of fossils numerically. This can only be expressed in such terms as excellent, good, fair, unsatisfactory, better or worse and defies any attempts of numerical calibration. Only a minority of fossils are, furthermore, reliable time indices and useful as index fossils. This situation parallels exactly that created by the relative (i.e. non-calibrated) nature of biological time, which provides us only with concepts of "before", "now" and "after". Any attempts at the quantification of biochronological correlation is, thus, precluded by the fundamentally qualitative and non-statistical nature of its most valuable data (index fossils)".

Jeletzky's (1965) remarks are true also for palynology applied to stratigraphy, but spores and pollen grains have a little different position. They are devoid of self-locomotion and are carried *en masse* by the wind currents and deposited more or less uniformly over vast areas. Thousands of specimens may be recovered from a small amount of sample. Hence the percentage diagrams of spore-pollen are a better representation of terms like excellent, good, fair, etc. This gives these latter relative terms almost a statistical value without invalidating Jeletzky's thesis.

Present Status of Palynology in Stratigraphy and Paleoecology

Palynological approach to deposits older than Quaternary is varied. The microflora represented by various fossil-pollen spectra manifest two types of changes viz., evolutionary and environmental. Evolutionary changes are well shown by plants because changes occur in mass. Leopold (1961) has described the dramatic expression of senescence in plants and believes that this step in the life cycle of plants may be a positive force in their adaptability in evolution. Seasonal phenomenon in terms of senescence of a crop and then its extinction is obvious. The same may take place in species, genera, and families during the long history of evolution. Such changes due to evolution are steady, take a long time, and are represented vertically and horizontally.

Changes due to shift in environment are abrupt and regional. Spores and pollen grains of the vegetation are disseminated into the atmosphere, mixed, and carried away by the wind currents and deposited on the continents and seas alike, and thus make

it possible to correlate continental and marine facies. Cousminer (1961) has shown the intimate relation between palynology, paleofloras and paleo-environments. Palynologic spectra provide a basis for pragmatic interpretation, and Wood (1955) and Kuprianova (1960) have stated that deep sea recovery of spores and pollen grains is adequate to make correlations.

For paleoecological interpretation, knowledge of the present-day flora is primary. In the interpretation of earlier sediments, many extinct forms and species are involved. Gaps in representation occur from lack of preservation, so comparing such spectra with the present day flora is more difficult. Using the "present is the key to the past", spores and pollen grains have always wandered into the air with the same pattern and been buried in sediments with similar honors. Still more research on the present day microflora and its preservation is required on the lines Ladd (1959) pointed out in consideration of faunas.

Non-representation of certain spores or pollen by nonpreservation will only affect the geological history of that individual species, but should not affect the paleoecological interpretations needed for stratigraphers or oil geologists. Ecology is reflected by the pattern of the association of the vegetation as a whole, rather than individual species, though in monoclimax type of vegetation, individual species may act as index species for the particular type of climate, topography or environment. Moreover such studies are relative among the deposits.

Hoffmeister (1960) has shown how paleoecological lines could be drawn and ancient shore lines delineated. Wilson (1961) has discussed the approaches of palynology and its limitations in economic geology. Cross (1964) reviewed the whole palynological approach in context of the geological problems and has discussed the essential needs in the various aspects of palynological studies. Glaessner (1964) expressed the opinion that palynology may help to fill peculiar gaps in the time ranges of foraminiferal index fossils where their evolution is slow or indistinct. Stratigraphically

and paleoecologically, it is valuable where foraminifera are absent or rare due to the type of facies. Schopf (1964) gave a detailed analysis of practical problems and the principles in the study of plant microfossils. Tschudy (1964) evaluated the relation of palynology and time stratigraphic determinations. Weber (1964) has shown that palynology has rectified many miscorrelations in Bahia Basin, Brazil, where the short span of time precluded marked evolutionary changes but pollen frequency curves were diagnostic.

Terminology for Spores and Pollen

Botanically, spores and pollen are differentiated on the basis of their functions which they perform during the life cycle of a plant. Spores are further divided into microspores and megaspores. A microspore is a reproductive body which germinates to form the male gametophyte and a megaspore germinates to form a female gametophyte. A pollen grain is the germinated microspore of the seed plant. Homosporous plants produce isospores which are difficult to distinguish from the microspores of heterosporous plants, which are similar in size and form, and are almost impossible to distinguish in the fossil state. The size ranges of microspores and megaspores also overlap. Many small spores may be megaspores, whereas many microspores may be larger than megaspores. However, in applied palynology in stratigraphy and paleoecology, spores and pollen grains in all their forms (micro-, iso- and mega-spores) have played equally important roles and functional differences do not jeopardize results.

Various terms have been introduced to cover 'spores and pollen grains' in palynological literature. The term 'microspore' has been used for all fossil spores less than 200 microns in diameter. Grayson (1956) proposed the term 'polospore' for pollen and/or spores. The arbitrary size limit of microspores has been kept less than 200 microns, and that of the megaspores at more than 200 microns. Felix (1961) has expressed the view that a new terminology or artificial limits are of questionable value because the

definitions of spores and pollen grains are based on functional characters, and functions cannot be recognized in the fossil state. Tschudy (1961) has introduced the term 'palynomorph' which includes all the micro-organisms used in palynological studies, including hystrichospheres, dinoflagellates, chitinozoans, acritarchs etc.

In the present study the term 'microspore' is used for spores and/or pollen grains and includes isospores and megaspores less than 200 microns in diameter, and the term 'palynomorph' is used in a broader sense where the other microfossils are also included.

Scope of the Project

In August 1963, Professor W. A. Clemens discovered mammalian fossils in the Upper Edmonton Member in the Scollard area at Kansas University (K.U.) Alberta locality 1 referred in this thesis as Scollard Locality 1. In the summer of 1964, a joint party from the University of Kansas and the University of Alberta discovered localities 2, 3, 17 and 18 and revisited the locality noted by L. S. Russell in 1952. The greatest number of mammalian specimens was recovered at locality 1. The mammalian fossils identified from the Scollard area are the following (Clemens, personal communication, 1964):

ALLOTHERIA

Mesodma formosa
Cimolodon nitidus

METATHERIA

Alphadon marshi
Didelphodon sp.
Pediomys n. sp. (small)

EUTHERIA

Gypsonictops sp.
Cimolestes n. sp. (larger than *C. incisus*)
Cimolestes incisus
"*Protungulatum*"

The same beds contain reptilian remains - lizard bones, dinosaur bones and teeth, turtles, crocodile scutes, garpike scales, fish vertebrae, amphibian bones, skate

teeth, etc.

The Upper Edmonton Member is considered to be of latest Late Cretaceous age. These beds are important because they show the presence of the two main groups of animals - dinosaurs which became extinct shortly after that time, and mammals, which developed and dominated the world shortly thereafter.

The Upper Edmonton Member is separated from the Middle Edmonton Member by a volcanic tuff-bed, known as the Kneehills Tuff. For detailed palynological studies, three sections have been selected - one below the Kneehills Tuff, another at the mammal occurrences and the third just above the second. Mammalian fossils have not been recorded locally below the Kneehills Tuff bed.

The purpose of this study is:

(1) To outline the palynological spectrum in the beds where mammal fossils occur, and in the beds deposited before and after.

(2) To evaluate any changes in the microflora.

(3) With the aid of the fossil microflora, to interpret vegetation and floral changes which might have taken place at that time.

(4) To interpret the paleoecology of the deposits through the microflora.

(5) To assess the potential of the microflora for calibration of the age of the strata for possible future studies.

<u>Previous Palynological Work Done in Upper Cretaceous</u>

Little palynological work has been done in the Upper Cretaceous Formations of the world. Just (1951) reviewed the work done on microfossils in the Mesozoic of the world, cited examples of the use of Mesozoic plant microfossils for stratigraphic work and stressed the need for more intensive collecting and study. Couper (1964) integrated spore-pollen correlation of the Cretaceous rocks of the northern and southern hemispheres. With the data in hand, he noted that Upper Cretaceous floras show ever-

increasing numbers of species of dicotyledonous pollen grains. Broadly he recognised a four-fold palynological subdivision in most of the areas considered, which has been correlated with the Cenomanian, Turonian, lower Senonian and upper Senonian.

Literature in North America

Radforth and Rouse (1954) classified the Cretaceous plant microfossils of potential importance to the stratigraphy of western Canadian coals. Radforth and Rouse (1956) have shown the floral overlap and floral transgression of major geological time boundaries illustrating with short range overlap of Cretaceous and Tertiary microfossils. Anderson (1960) studied the Cretaceous-Tertiary palynology of the San Juan Basin, New Mexico. Groot and Penny (1960) studied microspores in nonmarine sediments of Cretaceous age from Maryland and Delaware and described twenty species. The recovered microspores indicated that these deposits ranged from Lower Cretaceous to lowermost Upper Cretaceous. Funkhouser (1961) described and discussed the morphology, the possible relationships and distribution of fossil pollen of the genus Aquilapollenites and amended the original generic description. He outlined the range of Aquilapollenites (in western North America) from Albian through Upper Cretaceous (greatest diversity in uppermost Cretaceous) to Lower Eocene. Stanley (1961) described five more species of Aquilapollenites from samples belonging to the Hell Creek Formation (Maestrichtian) at Crow Butte, Harding County, South Dakota. Groot, Penny and Groot (1961) described many plant microfossils and interpreted the age of the Raritan, Tuscaloosa and Magothy Formations as belonging to Late Cretaceous time in the eastern United States. Stanley (1961a) described a new sporomorph genus Wodehouseia from Late Cretaceous and early Paleocene age from the continental sediments of north-western south Dakota. Pierce (1961) described and reported a number of plant microfossils from lower Upper Cretaceous from Minnesota. Tschudy (1961) used palynomorphs as the indicators of facies environments in Upper Cretaceous and lower Tertiary strata of Colorado and Wyoming.

Brown and Pierce (1962) attempted palynological correlations of three cores, situated 80, 90, and 120 miles apart, from the Cretaceous Eagle Ford Group and they compared the palynologic correlations with the detailed electric log correlations carried between intermediate wells. The two correlations agreed closely, and illustrated the regional correlation value of palynomorphs in marine sediments. Rouse (1957) described the Upper Cretaceous plant microfossils from western Canada and classified them under a different system of nomenclature. Rouse (1962) described spores, pollen grains and other plant microfossils from the Burrard Formation of the Vancouver area. Geologically, the formation has been suggested as of Eocene age, but the palynomorph assemblage suggests that both Upper Cretaceous and middle Eocene strata are represented within the formation.

Crickmay and Pocock (1963) delineated Campanian, Paleocene and Eocene strata in the Vancouver area, British Columbia, with the help of the palynograph frequencies. Evitt (1963) described the occurrence of fresh water alga Pediastrum in Cretaceous marine sediments (Lower Cretaceous of Pakistan and Upper Cretaceous of California) and suggested that Pediastrum may not always indicate nonmarine environment, and that allied species of Pediastrum might be of marine origin in Lower Cretaceous strata. Upshaw (1963) recorded the occurrence of spores belonging to the Mesozoic form genus Aequitriradites from lower Upper Cretaceous sediments of north-western Wyoming.

Leopold and Pakiser (1964) reported a diverse assemblage of fossil pollen representing primarily dicotyledonous flora from the pre-Selma Upper Cretaceous strata. They discussed the depositional condition and paleoecology. Newman (1964) made palynologic correlations of Late Cretaceous and Paleocene formations in north-western Colorado. Sloan (1964) discussed paleoecology of the Cretaceous-Tertiary transition in Montana. Stover (1964) compared the microspore assemblage from Lower Cretaceous strata mapped as Arundal Clay and the Upper Cretaceous Magothy Formation in Maryland with those from the Lower Cretaceous Wealden sequence in England. Upshaw (1964)

zoned the Upper Cretaceous Frontier Formation, near Dubois, Wyoming on palynological data.

Hills and Weiner (1965) described fossil fern, Azolla geneseana from Upper Cretaceous Edmonton Formation of western Canada.

Pertinent Foreign Literature

Cookson (1955) reported the occurrence of Paleozoic microspores in Australian Upper Cretaceous and lower Tertiary sediments. Cookson and Dettman (1958) described some trilete spores from upper Mesozoic deposits in the Eastern Australian region and they (1959) established the form genus Schizosporis from the Cretaceous deposits of Australia. Couper (1953, 1953a, 1960) described several spores and pollen grains from the upper Mesozoic and Cenozoic of New Zealand and recorded distribution of Proteaceae, Fagaceae, and Podocarpaceae in some Southern Hemisphere Cretaceous and Tertiary beds. Cookson and Eisenack (1962) described some Cretaceous and Tertiary microfossils of uncertain affinity from Western Australia. Norris (1962) described type specimens of Mesozoic and Cenozoic spores and pollen grains from New Zealand.

Ross (1949) investigated pollen and spore bearing clay of Scania of Senonian age from the Kristianstad District of south Sweden. Wetzel (1953) gave a resume of microfossils from Upper Cretaceous flints and chalks of Europe. Couper (1958) did systematic and stratigraphic studies of British Mesozoic microspores. Wetzel (1961) described new microfossils from Baltic Cretaceous flintstones including dinoflagellates, hystrichospheres, radiolaria, echinoderm sclerites, scolecodont assemblages, and gave taxonomic comments. Groot and Groot (1962) described plant microfossils from Aptian, Albian and Cenomanian deposits of Portugal. Koch (1964) reviewed the fossil floras and nonmarine deposits of west Greenland.

Bolkhovitina (1953) described characteristic spores and pollen from the

Cretaceous of the central part of the U.S.S.R. Voyevodeva and Khaikina (1960) described spore-pollen complexes of north-east U.S.S.R. belonging to Upper Cretaceous. Zalinskaya (1960) showed the significance of angiospermic pollen for the stratigraphy of the Upper Cretaceous and Paleogene. Khlonova (1960, 1961a, b) described many spores and pollen grains from the Upper Cretaceous of Siberia in U.S.S.R. Samoilovich and Mtchedlishvili (1961) described and illustrated many genera and species from Jurassic to Paleocene formations of Russia. Khlonova (1962) described a good number of spores and pollen of the Upper Cretaceous of the eastern part of the western Siberian lowland. Bolkhovitina (1962) traced the history of the family Schizaeaceae in the geologic past on the basis of spore studies and noted a reduction of generic distribution of Schizaeaceae during Upper Cretaceous and Tertiary of Siberia and Europe as compared to their distribution in Lower Cretaceous. Brattseva (1962) reported data on the fossil flora from beds corresponding to the Cretaceous-Paleogene boundary in the Zeya-Bureya depression in Russia. Schopf (1964) reviewed the present position of palynology in Russia, taking into account the literature and its application to exploration there.

Van der Hammen (1954, 1957) described the microflora of Maestrichtian and Tertiary deposits of Colombia and discussed climatic periodicity and evolution. Van der Hoeken-Klinkenberg (1964) worked on palynological investigations of some Upper Cretaceous sediments in Nigeria and found striking similarity with the conclusions of van der Hammen (1957) for the Upper Cretaceous sediments in Colombia. Puri (1963) recovered a number of microfossils from the Cretaceous and Tertiary deposits of Nigeria. Puri's (1964) pollen analytical studies reveal that, in the Cretaceous to Eocene of the Nigerian tropics, a vegetation, in which Nothofagus, Podocarpus and form genera resembling Araucaria and other southern gymnosperms were prominent, are common to the fossil vegetation for the same periods in Australia, New Zealand and the Indian mainland. He is of the opinion that there were prominent changes in the vegetation of the African tropics from the Cretaceous through Tertiary and Pleistocene.

Stover (1964a) instituted one new genus and four species of ephedroid pollen from the Albian-Turonian sequence in the Senegal Basin, West Africa, revealing morphologic features unknown in Recent Ephedra pollen, indicating wide diversity of Cretaceous gnetalean pollen.

Literature on Other Microfossils

Sarjeant (1961) discussed and reviewed the literature and classification of the hystrichospheres and has included most of the work done earlier in the bibliography. More microplankton have been described later by Cookson and Eisenack (1960, 1961, 1962) from the Cretaceous sediments of Australia. Evitt (1964) discussed the characters of dinoflagellates and their use in petroleum geology.

Hanna (1927, 1934) recorded diatoms from the Cretaceous beds of California. Long, Fuge and Smith (1946) reported diatoms from the Moreno Shale. Lohman (1964) discussed the stratigraphy and paleoecologic significance of the Mesozoic and Cenozoic diatoms of California and Nevada.

CHAPTER TWO

STRATIGRAPHY

Geology of the Area - Edmonton Formation

"Edmonton" strata were first named by Selwyn (1874) while analysing the coal beds near Edmonton and were called "Edmonton coal beds". Tyrrell (1887) designated this formation the 'Edmonton Series'. The Edmonton Formation has been surveyed, studied and described by Allan and Sanderson (1945) in great detail and given the rank of Formation. The distribution of the Edmonton Formation given by them is cited below: "As originally deposited, the Edmonton Formation covered most of Alberta east of the foothills and south of latitude 56°. It grades into the thinner Fox Hills Formation to the east and south, and on the west apparently becomes a part of the thick, undifferentiated deposits of the Upper Montana subdivision of the Cretaceous. Similar formations that are stratigraphically equivalent in the western States are known as the Horsethief Sandstone in Montana, and the Lennep and Meeteetse in Wyoming". They reported the thickness of the Edmonton Formation 1,000 to 1,200 feet in the plains and up to 2,500 feet thick in the foothills.

The lithologic characteristics given in the "Lexicon of Geologic Names in the Western Canada Sedimentary Basin and Arctic Archipelago" (1960) are cited below:

"Vertical and lateral lithologic variations are notable in the Edmonton Formation. It consists predominantly of fresh to brackish water, fine-grained sandstone, calcareous sandstones, sandy shales, bentonitic sandstones and shales, bontonite, ironstone nodules and bands, carbonaceous shales, and coal. Bentonite is conspicuous throughout the series of beds, with shales and sandstones containing appreciable quantities. Pure bentonitic beds are locally present. Hard, flaggy sandstones occur in well-defined horizons. These cap the mesas, buttes, and plateaus found where badland topography is developed. In east-central Alberta a tuff horizon referred to as the Kneehills Tuff occurs within the Edmonton Formation. This bed forms a reliable stratigraphic marker over con-

siderable distances and is tentatively recognised as far south as the Oldman River (Tozer, 1952). The Edmonton Formation is remarkably free of coarse clastic material".

Discussing the mode of deposition of the Formation, Allan and Sanderson (1945, p. 24) gave the following account:

"The Edmonton Formation consists largely of sediments deposited under fresh and brackish water conditions, in shallow freshwater basins, or in estuaries and deltas, or in littoral zones along the border of an advancing or retreating sea. Some of the members of this Formation were deposited as mud flats and along flood plains that were exposed above the water level for short spaces of time, possibly seasonal. Some of the beds, particularly those containing carbonaceous material, originated in enclosed basins or swamps. Crossbedding, current marks, lensy structure, nodular masses, ironstone bands, erosion during deposition, younger beds enclosing fragments of older beds, ... are a few of the characteristics that prove the continental mode of deposition of the sediments of the Edmonton Formation".

Allan and Sanderson (1945) were of the opinion that the Edmonton Formation is overlain disconformably by the Paskapoo Formation while Campbell (1962) considered it to be conformable. Rutherford (1947), Russell (1950), Tozer (1953), Ower (1958) and Elliott (1958) described it as conformable at some places and disconformable at other places. The Edmonton Formation is underlain by the marine Bearpaw Formation and at some places is underlain by the Belly River Formation. The Edmonton Formation is correlated with the Blood Reserve and the St. Mary River Formations of the southern plains, possibly with the lower part of Willow Creek Formation, the Eastend, Whitemud, Battle and Frenchman Formations of the Cypress Hills; and the Fox Hills, and the Lance Formations of Montana. The lower part of the Edmonton Formation is supposed to be equivalent to the upper part of the Pierre Formation and in the foothills, it is equivalent to the upper part of the Wapiti and Brazeau Groups.

Allan and Sanderson (1945) divided the Edmonton Formation into three members:

Upper Edmonton Member

Middle Edmonton Member

Lower Edmonton Member

Upper Edmonton Member: Allan and Sanderson (1945) included the beds above the Ardley seam up to an erosional unconformity at the base of the Paskapoo Formation in the upper part of the Upper Edmonton Member, and they drew the base at the top of a dark shale which includes the volcanic ash bed named by Sanderson as the Kneehills Tuff. The Kneehills Tuff has been correlated with a similar bed in the Cypress Hills area in the Battle Formation. There are two to four beds of coal lying below the Ardley seam. The remainder of the Upper Edmonton is composed of light colored sandstones and siltstones, with local lenses of more argillaceous and ferruginous strata. According to Allan and Sanderson the thickness of the Upper Edmonton Member ranges from 200 to 290 feet.

In the Upper Edmonton Member, mammal remains have been recovered 45' above the Blackmud bed (= Battle?) which carry the Kneehills Tuff at the top in Scollard Locality 1. The mammalian fossils recovered from Scollard Locality 18 are immediately above the Blackmud beds. An erosional unconformity is noted below these beds in Upper Edmonton Member and the beds referred to here as "Blackmud".

Middle Edmonton Member: Allan and Sanderson (1945) placed the contact between the Lower and Middle Members of the Edmonton Formation at the top of the thin marine bed named the Drumheller marine tongue which contains *Corbicula occidentalis ventricosa*. The uppermost bed at the top of the Middle Member is dark grey to mauve-black shale (= Battle?) enclosing selenite crystals (these dark beds shall be referred in this study as "Blackmud") and includes the thin silicified tuff layers (Kneehills Tuff). The Blackmud beds are underlain by a prominent, white, bentonitic shaly sandstone which shall be referred here as "Whitemud" beds (= Whitemud Formation of Cypress Hills?). There is one coal seam about 50 feet below the tuff horizon. The intervening beds are interlensing bentonitic sandstones and siltstones of drab color.

Below this coal seam there is another. The interval between them ranges from 50 to 100 feet. Rocks below this seam have slightly less admixture of calcareous and ferruginous matter. The middle member is approximately 300 feet thick.

Lower Edmonton Member: The average thickness of the Lower Edmonton is about 600 feet. The upper 25 feet of the member is marine strata of shoreline type, composed of arenaceous limestone with abundant *Corbicula occidentalis ventricosa*; bluish siltstone - poor in bentonite, with no fossils; and arenaceous limestones with abundant *Ostrea glabra coalvillensis*. At some localities *Ostrea* and *Corbicula* occur together in the thinner marine stratum. The rest of the member has a prevalence of coal seams, a higher content of bentonite in the rocks, and greater variation in the lithology.

Ower (1960) studied surface samples and well logs of the Edmonton Formation of central Alberta and noted a thickness of 1,100 to 1,700 feet. He divided the Formation into five members viz. A, B, C, D, E, serially from older to younger and distinguished mainly on lithologic grounds. He correlated the lowest four members, i.e., A, B, C, and D, with the Fox-Hills-Pierre in age and the uppermost E with the Lance Formation of Montana. The continuous Kneehills Tuff throughout the area has been taken as a marker between Lance and pre-Lance deposition. Ower is of the opinion that there is no evidence of irregular differential erosion of the Edmonton Formation before deposition of the Paskapoo Formation and if a disconformity exists between the Paskapoo and Edmonton Formations, it may be at the base of the massive sandstone above the Ardley seam at Ardley and above the Pembina seam on the North Saskatchewan and Pembina Rivers and thus the thickness of the member E or Upper Edmonton (Lance equivalent) would be reduced to 184 feet in the Ardley surface section.

Elliott (1960) in studying the subsurface correlation of the Edmonton Formation, recognized certain coarse sandstones at the base of the Paskapoo Formation. On this basis it "requires a disconformity, and a major one, between the base of the Paskapoo and the underlying Edmonton Strata" (op.cit.p. 336).

Paleontology of the Edmonton Formation

Invertebrate Fauna in Edmonton Formation

The following is the list of invertebrate fauna of the Edmonton Formation given by Allan and Sanderson (1945):

Freshwater and Terrestrial

PELECYPODA

Prionodesmacea

Unionidae

Unio danae M. & H.
U. consuetus Whit.
U. minimus Warren
U. sandersoni Warren
U. priscus M. & H.
U. senectus White
U. albertensis Whit.

Teleodesmacea

Cyrenidae

Sphaerium recticardinale M. & H.
S. heskethense Warren

GASTROPODA

Ctenobranchiata

Viviparidae

Vivipara conradi M. & H.
V. reynoldsanus M. & H.
V. prudentius White
V. trochiformis M. & H.
Campeloma sp.
C. producta White

Valvatidae

Valvata filosa White
V. bicincta Whit.

Pleuroceridae

Goniobasis nebraskensis M. & H.
G. tenuicarinata M. & H.
G. convexa M. & H.
G. sp.

Hydrobiidae

Hydrobia sp.

Pulmonata

Bulimulidae

Thaumastus limnaeiformis var. *tenuis* Warren
T. limnaeiformis M. & H.

Limnaeidae

Acroloxus minutus M. & H.
A. radiatulus Whit.
Limnaea tenuicostata M. & H.

Physidae

Physa copei White
P. canadensis Russell

Helicidae

Patula angulifera Whit.
P. obtusata Whit.

Marine

BRYOZOA

Cheilostomata

Membraniporae

Conopeum bicystosum Sanderson

Marine and Brackish

PELECYPODA

Prionodesmacea

Ostreidae

Ostrea glabra M. & H.
O. glabra lata Sanderson

O. glabra coalvillensis Sanderson
O. glabra expansa Sanderson

Nuculidae

Nucula suplana M. & H.

Parallelodontidae

Cucullaea shumardi M. & H.

Anomiidae

? *Anomia micronema* M.
Anomia cf. *perstrigosa* Whit.

Mytilidae

Mytilus albertensis Warren
Modiola dichotoma Whit.
? *Crenella elegantula* M. & H.
Volsella meeki E. & S.

Teleodesmacea

Cyrenidae

Corbicula cytheriformis M. & H.
C. occidentalis M. & H.
C. occidentalis var. *ventricosa* Sanderson

Veneridae

Callista deweyi M. & H.
C. nebraskensis M. & H.

Corbulidae

Corbula subtrigonalis M. & H.
C. perangulata Whit.

Saxicavidae

Panope ? *simulatrix* Whit.
P. curta Whit.

GASTROPODA

Ctenobranchiata

Naticidae

Lunatia obliquata (Hall & Meek)
L. occidentalis M. & H.

Comments on the Edmonton Formation on the Basis of the Invertebrate Fossils

Allan and Sanderson (1945) recorded freshwater and terrestrial invertebrates from the bottom to the top of the Formation, which were commonly found in small numbers in scattered spots. This limited fauna from such an extensive formation indicates the singular isolation of the basin from other contemporaneous areas which had very stable and uniform conditions of environment for a long time.

The marine invertebrates can be correlated with Upper Cretaceous faunas in eastern Montana and the Dakotas. The marine fauna is numerically small in comparison to that of formations like the Fox Hills. This disparity has been accounted for by Allan and Sanderson with the interpretation that the marine deposits of the Edmonton Formation represent a very transient incursion of the sea, the duration of which was too short to permit immigration of representatives of all the forms found in Montana.

Vertebrate fauna in Edmonton Formation:

Williams and Dyer (1930) gave the following list of vertebrate fossils from the Edmonton Formation:

Pisces

Myledaphus bipartitus Cope
Acipenser sp. indet.
Lamna sp.
Palaeospinax ejuncidus Lambe
Diphodus ? longirostris Lambe
Priscacaridae gen. et sp. nov.

Reptilia

Leurospondylus ultimus Brown
Aspideretes sp.
Trionychid
Basilemys sp.
Champsosaurus sp.
Crocodilia gen. et sp. indeterminable
Albertosaurus sarcophagus Osborn
small theropod
Struthiomimus brevetertius Parks

? Ornithomimus velox Marsh
Ornithomimus sp.
Ornithomimipus angustus Sternberg
Troodontidae gen. undetermined
Thescelosaurus warreni Parks
Thescelosaurus sp.
Saurolophus osborni Brown
Hypacrosaurus altispinus Brown
Cheneosaurus tolmanensis Lambe
Edmontosaurus regalis Lambe
Thespesius edmontoni Gilmore
Anchiceratops ornatus Brown
Anchiceratops sp.
Leptoceratops gracilis Brown
Arrhinoceratops brachyops Parks
Ankylosaurus magniventris Brown

Mammalia

? Eodelphis sp.

To the above list the following dinosaurian fauna which have been mentioned by Sternberg (1940, 1945, 1947) are added:

Anatosaurus
Anodontosaurus
Edmontonia
Gorgosaurus
Parkosaurus
Stegosaurus
Thescelosaurus edmontonensis Sternberg
Triceratops
Tyrannosaurus ?

On the basis of the vertebrate fossils, William and Dyer (1930) were of the opinion that the Edmonton Formation is closely correlative with the Lance Formation.

Plant Fossils from Edmonton Formation

Bell (1949) listed the flora of the Edmonton Formation which remained limited to about 24 species, distributed among 14 families and 20 genera. The representation of fossil plants is as follows: Equisitae 1, ferns 1, cycadophytes 3, ginkgophytes 3, conifers 6, and dicotyledons 10. Among conifers Sequoiites and Elatocladus intermedius are abundant in the lower part of the formation. Platanus is common among the dicotyledonous trees in the upper part of the Edmonton Formation. Dombeyopsis and Vitis are abundant in the lower part.

Bell (1949) divided the flora into two subfloras, one recovered above the Kneehills Tuff bed in the Upper Edmonton, and the other below the Kneehills bed in the rest of the formation.

The flora of the lower part of the Edmonton Formation recorded by Bell (1949) is given below:

Equisetum perlaevigatum Cockerell
Nilssonia sp.
N. serotina Heer
Ginkgoites sp.
Carpolithus (Ginkgoites?) fultoni Bell
C. (Ginkgoites?) kneehillensis Bell
Torreyites tyrrellii (Dawson) Bell
Cunninghamiostrobus? sp.
Sequoiites artus Bell
S. dakotensis Brown
Elatocladus intermedius (Hollick)
Thuites interruptus (Newberry)
Juniperites gracilis (Heer) Seward and Conway
Trochodendroides arctica (Heer)
Jenkinsella arctica (Heer) Bell
Dombeyopsis nebrascensis (Newberry) Bell
Nymphaeites angulatus (Newberry) Bell
Vitis stantoni (Knowlton) Brown

The assemblage of the flora is characteristic of formations of the approximate age of the Fox Hills and the lower part of the Medicine Bow in the United States.

The flora recorded from the Upper Edmonton is:

Filicites knowltoni Dorf
Carpolithus (Cycadinocarpus?) ceratops (Knowlton)
Sequoiites dakotensis Brown
Platanus raynoldsii integrifolia Lesquereux
Platanophyllum sp.
Anona robusta Lesquereux
Nymphaeites angulatus (Newberry) Bell
Vitis stantoni (Knowlton) Brown
Fraxinus leii Berry

All species are long ranging and are present in the Lower Edmonton Formation, except four diagnostic species viz: Filicites knowltoni, Carpolithus ceratops, Anona robusta and Fraxinus leii. These are characteristic forms of the Lance Formation and two of these, i.e. Carpolithus ceratops and Fraxinus leii occur in the Frenchman Formation.

Hence Bell (1949) has concluded that the upper part of the Edmonton Formation is equivalent in age to that of the Lance.

Kneehills Tuff Bed

With the foregoing description, it is evident that the Kneehills Tuff bed has been recognized as the marker bed between Middle Edmonton and Upper Edmonton. Major changes in fauna and flora have also been noted as discussed earlier (William and Dyer, 1930; Sternberg, 1947; Bell, 1949). Ower (1960) and Elliott (1960) have also shown this bed to be useful as a stratigraphic and structural marker.

Allan and Sanderson (1945) gave the name Kneehills Tuff to the volcanic ash bed in the Edmonton Formation on the Red Deer River east of the town of Ardley, outcropping down the valley of the Red Deer River to a point west of Morrin in township 31 and up Kneehills Creek as far as Carbon. To the south and east, they detected it on the north flank of Wintering Hills and on the south slope of Hand Hills. The maximum thickness of the bed wherever observed is seldom more than eight inches.

The silicified band of tuff occurs at different levels within the Blackmud beds and from place to place different silicified bands become locally known as the Kneehills Tuff. Figure 2 shows two of these potential bands in locality 1 and it is undoubtedly the lower one that is present at locality 18.

Ritchie (1960) has described the Kneehills Tuff as a light brownish-grey, weathering lighter, hard, massive, very fine grained, having a phonolithic ring when struck with a hammer, usually structureless, sometimes showing vague bedding features, breaking into sharp angular fragments forming a talus. Vugs filled with opaline silica or bentonite clay are visible. He has also given the microscopic features of the Tuff bed.

On the basis of the potassium-argon dating method, Ritchie (1960) assigned an age to the Kneehills Tuff of 70 million years plus or minus two million years. He inter-

preted the individual tuff lenses to be wind-carried material originating from separate explosive outbursts at the source, and this ash was deposited in freshwater basins and altered diagenetically. He correlated the Kneehills with a source in the igneous rock to the southwest in Montana. Folinsbee, Baadsgaard and Lipson (1961) assessed the age of the Kneehills Tuff at 66 million years by the potassium-argon method. Shafiqullah (1963) also determined the age of these beds as 66 million years ± one million years.

Age of the Upper Edmonton Member

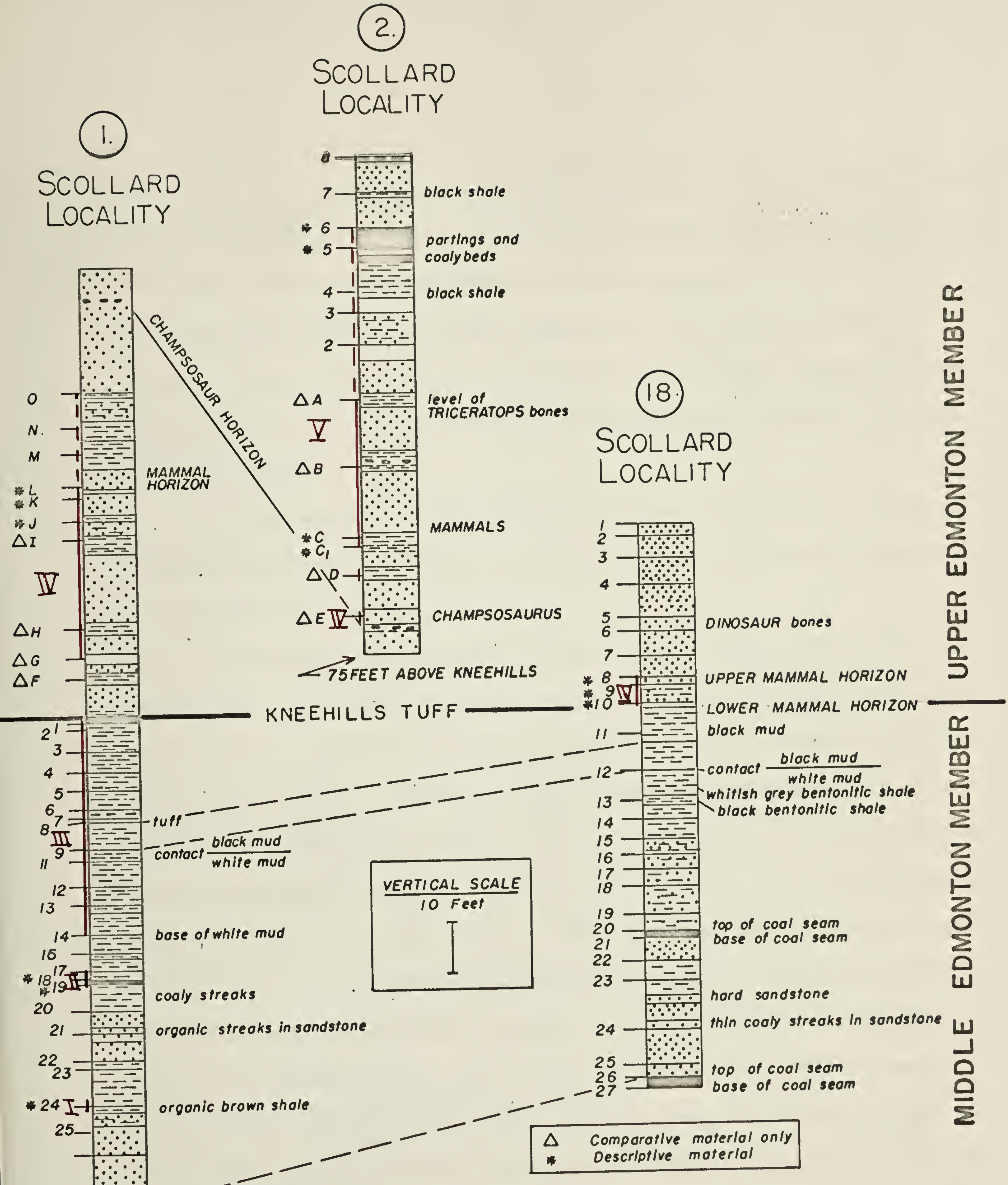
The transition from Lower-Middle Edmonton to Upper Edmonton at the horizon of the Kneehills Tuff shows a marked break in lithology and saurian fauna with the introduction of *Triceratops*, *Tyrannosaurus*, *Ankylosaurus*, and *Thescelosaurus* (Sternberg, 1947). The difference in the flora has also been shown by Bell (1949) with the introduction of *Carpolithus ceratops* and *Fraxinus leii*.

Folinsbee *et al*. (1961) have determined the potassium-argon dates for the Pembina or Ardley Seam at Whitecourt, which lies 200 to 300 feet above the Kneehills Tuff, as 63 million years. Shafiqullah (1963) has determined the potassium-argon dates for Pembina Coal, Whitecourt, Alberta, as 64.4 million years and that of upper Ardley Coal, Red Deer River Valley, Alberta, as 63 million years.

Thus the Upper Edmonton Member has been correlated with the Lance Formation which is upper Maestrichtian. The Cretaceous-Tertiary boundary has been dated as 63 million years old.

Locality and Material

Samples for palynological analysis were collected from the Scollard area. Scollard "town" is situated in the southern part of central Alberta and lies at 112° 50'W; 51° 56'N. The sites of the samples collected are about five miles west of Scollard on the high banks of the Red Deer River. The three sample collection sites are named,

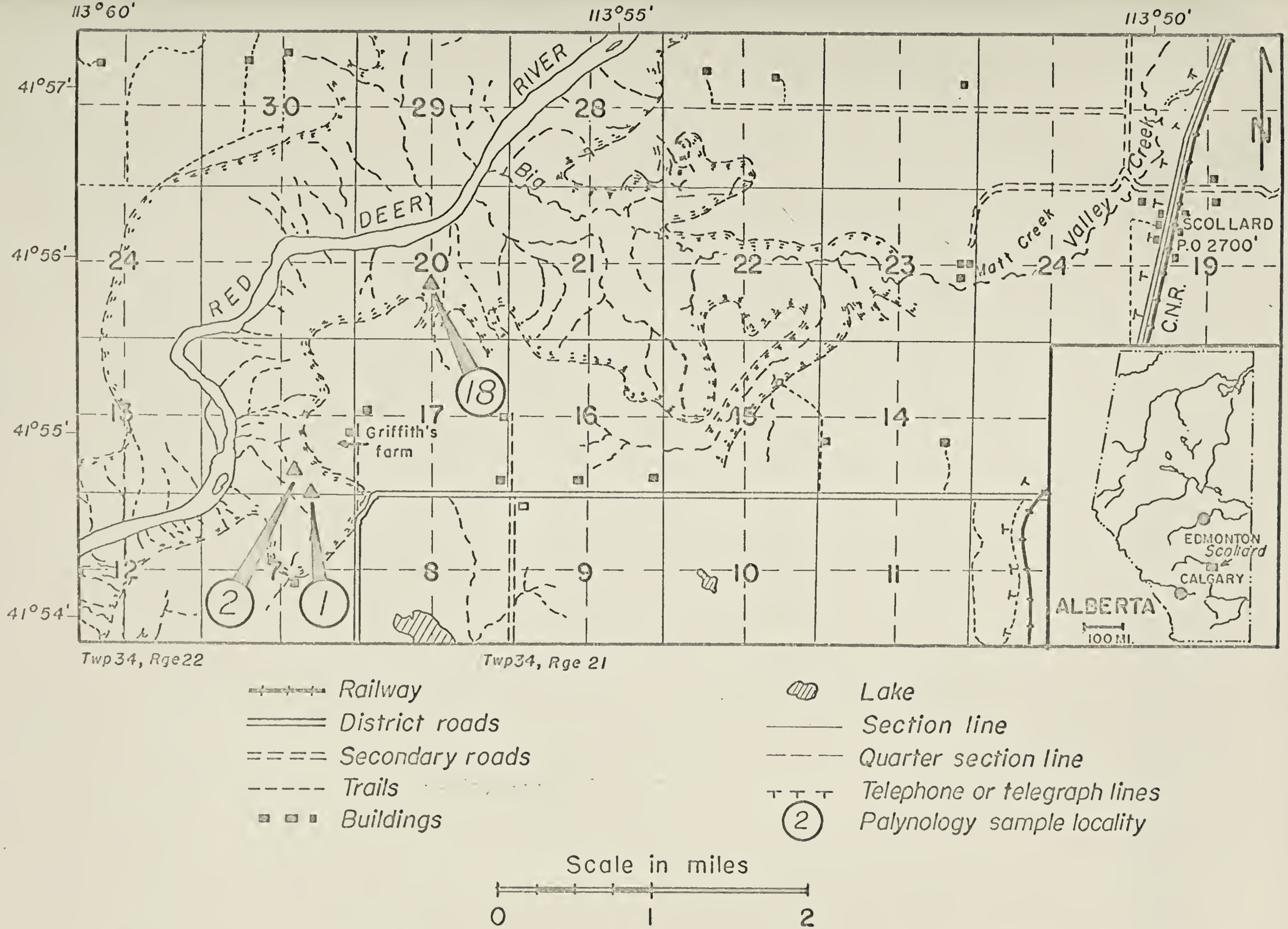


STRATIGRAPHIC POSITIONS OF PALYNOLOGY SAMPLES

Scollard Locality 1, 2 and 18. Localities 1 and 2 fall in lsd. 2, sec. 18, tp. 34, rge. 21 and locality 18 is in lsd. 6, sec. 20, tp. 34, rge. 21, W. 4th mer. The detailed map of the area showing the localities of samples collected is given in figure 1, and the aerial photo of the same area showing the localities of samples collected is given in Plate XIV. Most samples were collected at two foot intervals. Care was taken to check lithological changes in the beds. Samples were also collected at different lithologic contacts. Shales, clays and coal samples were collected especially for the palynologic investigations, because such beds have been found to preserve rich assemblages of microfossils.

The sample positions and the lithologic features in the sections are shown in stratigraphic column given in figure 2, which also show the stratigraphic relation of the three localities to each other.

Fossil mammal bones have been recovered from all three localities above the Kneehills Tuff. This was the time in the geologic past when the dominant saurian fauna coexisted with the early mammalian fauna, and after this the saurian fauna waned to extinction rather abruptly, and the mammalian fauna bcame abundant and explosively dominated the geologic scene thereafter. For the present study, to examine the microfloral changes, three horizons were selected. Samples 18, 19, and 24, from below the Kneehills Tuff bed at Scollard Locality 1, were studied to determine the floral pattern before the local advent of mammals and during the domination of dinosaurs but before the deposition of the Kneehills Tuff. Samples L, K, and J of Scollard Locality 1, C and C_1 of Scollard Locality 2; and 8, 9, and 10 of Scollard Locality 18 are from the beds from which mammal bones have been collected. These samples were studied to determine the vegetational pattern when primitive mammals intruded the sovereignty of dinosaurs in this area. Samples 5 and 6 from Scollard Locality 2 are above the mammal beds, and these have been examined to find out the paleoecological pattern which was most suitable for the explosive evolution of mammals and the extinction of dinosaurs.



Map of Scollard area showing localities of Palynology samples

The record of the last dinosaur, Triceratops, is at the position of sample A at Scollard Locality 2.

Samples lying in between these horizons have also been examined for comparison to see how and in what stages the changes in microflora took place during this time.

CHAPTER THREE

PALYNOLOGIC PREPARATION AND STUDY TECHNIQUES

Franz Schulze (1855) first described the use of potassium chlorate and nitric acid in macerating coal, in order to render microscopic structures clear. Since then the application of palynology has extended to sediments other than coal, new techniques were tested and introduced by various workers. Palynologic preparation techniques need to be such as to dissolve or separate the matrix from the microfossils, render morphologic structures of microfossils clear, and to be less time-consuming and easy to process.

Brown (1960) compiled and described the various palynologic techniques practiced by many workers on diverse aspects of palynology. Arms (1960) suggested a silica depressant method for concentrating fossil pollen and spores from samples of arid land sediments having a low pollen content. Staplin, Pocock, Jansonius and Oliphant (1960) gave an elaborate method dealing with different types of sediments. Spielholtz, Thomas and Diehl (1962) advocated the use of a mixture of solid periodic acid and 50% perchloric acid for differential oxidation of coal. Felix (1963) recovered microfossils by the mechanical disaggregation of shales without the use of acids, only by washing the sediments by a rotary mechanism and using a bromoform separation. Artamonova and Medredeva (1963) described the methods of extracting microspores from petroleum and the water of crude oil deposits. Wilson (1959) suggested a water-miscible mountant for palynology and Schoff (1960) gave the method of preparing double cover-glass slides for plant microfossils.

In the preparation of the palynologic slides of sample for the present study, the following steps were used.

A. Collection of Samples

1. In any sampled section, samples were usually taken at two-feet intervals, at lithologic changes, and from thin coaly, shaly or clay beds.

2. The samples were taken at a depth of two feet in order to avoid surface contamination. Each sample usually represented four to six inches of section.

3. Samples were packed in polythene bags and each bag was labelled with locality and sample numbers.

B. Mechanical Processing

1. 10 to 20 grams of sample were selected for processing.

2. Sample was broken to pea-size and transferred to a beaker labelled with the number and locality.

C. Chemical Processing

(After every step described below, samples were washed thoroughly by centrifuging with distilled water).

1. Removal of carbonates: With a drop of dilute hydrochloric acid (10%), the presence of carbonates was tested. If present, the sample was covered by 10% hydrochloric acid and kept until all the carbonate was dissolved. In the absence of the carbonates, this step was omitted.

2. Removal of silicates: The samples were treated with hydrofluoric acid. The time required for dissolving the silica of individual samples differed, hence a periodic check was kept to see when silica disintegration was complete.

3. Residue was treated with warm 10% hydrochloric acid to remove fluorosilicates. Sometimes this treatment dissolved other inorganic matter.

4. Oxidation of carbonaceous material: The residue from the above was treated with freshly prepared Schulz solution. Periodic checks were made to see that microfossils were not being destroyed.

5. Superfluous organic debris was dissolved by suspending the sample in 10% potassium carbonate solution for about 10 to 15 minutes until the sample turned dark brown. The sample was then diluted with distilled water and washed thoroughly. Care was taken to see that fragile microspores were not dissolved. The samples were washed and cleared of debris by centrifuging at different speeds and checking the discarded solution for microspores.

6. In a few samples, where the inorganic matrix could not be removed, the

microspores were separated by a heavy liquid - a mixture of zinc iodide, potassium iodide and cadmium iodide. The specific gravity of the liquid was kept at 2.3. If this step was not needed, the slides were prepared directly from the residue.

Heavy liquid treatment:

(a) Sufficient heavy liquid to cover the sample was mixed with it until most of the material was suspended. The greater the dispersion of the material in the liquid is, the better the separation.

(b) Sample was centrifuged for a longer time.

(c) Upper portion of the fluid was decanted into a beaker.

(d) Microspores lighter than 2.3 specific gravity were concentrated in the decanted liquid. This was diluted approximately five times and samples were left overnight for settling of the microspores.

(e) The upper portion of the sample was decanted and discarded after checking for microspores. The lower portion was centrifuged and washed with distilled water. Sometimes gelatinous precipitates of iodides appear which are removed by adding a couple of drops of dilute hydrochloric acid.

(f) The recovered material was mounted on the slides.

D. Preparation of the Slides

1. A little organic residue was taken with a spatula or needle with a fine end, and placed in the middle of the slide.

2. To stain the microspores, a drop of safranin 0 was well mixed with the sample. The microspores take the stain in about half a minute.

3. Two or three drops of corn syrup were well mixed with the sample, which was spread to cover about two thirds of the slide. The material migrating to the edges of the slide was saved.

Corn syrup as purchased from the market is very viscous. A little water was added and the viscosity made so that the drop would not flow out too swiftly, nor would

it arrest the air bubbles. A little phenol was added to the syrup to save it from fungal or bacterial infections.

Microspores being light in weight, have a tendency to migrate towards the edges of the fluid. Care was taken to bring the liquid from the edges to the centre by spatula or needle frequently until the liquid was established.

4. One third of the slide was left for labelling the sample and slide number.

5. 8 to 10 slides were prepared for every sample.

E. Examination of Samples

Generally, three slides for every sample were examined. For the frequency counts, the slides were traversed at a magnification of X100 lengthwise along lines 5 mm apart. A rough estimate of the relative frequency of each species in each sample was made by counting the identifiable and well-preserved specimens and recording abundant (10 or more specimens), common (5 to 9 specimens), rare (2 to 4 specimens), or single (1 specimen). The rough estimate of the relative frequency of species is adopted along the lines recorded by Singh (1964). More slides were examined for rarer specimens.

F. Photomicrography

Photomicrographs were taken by a Orthomat Leitz microscopic camera. Agfa IFF 35 mm film was used and the photographs were printed on Kodak Polycontrast F paper. Polycontrast filters were used to produce sufficient contrast on the prints. For illustrating the details of the morphology, photomicrographs were taken under oil immersion.

G. Illustrations

All the figured specimens are shown on the plates at a magnification of X 500 to give the idea of relative size differences. Finer details are illustrated at the higher magnifications.

CHAPTER FOUR

PALEOECOLOGICAL INTERPRETATIONS AND AGE CALIBRATION

The microfloral assemblages recovered from the Edmonton Formation in the brief succession embracing the Cretaceous mammal-bearing beds enables us to divide this sequence into five "zones". The sequence embraces that portion of the Upper Edmonton above the Kneehills Tuff and below the Ardley coal-seam horizon and the upper portion of the Middle Edmonton Member lying below the Kneehills Tuff and roughly embracing the two units of the Edmonton Formation termed the Blackmud beds and the Whitemud beds, with a subjacent coaly sequence. The breaks or changes in the microfloral spectra are based, in this study, on the appearance and disappearance of species and genera rather than on percentage composition.

The palynological "zones" are distinguished by the following suites arbitrarily numbered from bottom to top as Microfloral Assemblages I-V. The boundaries between the "zones" are not defined as the emphasis of study was directed towards the contrasting suites rather than the transitional portions.

The diagnostic (and figured) material comes from the following samples:

Microfloral Assemblage V: Scollard Locality 2, Samples C_1, C, B, A, and 5 and 6; 90 to 150 feet above the Kneehills Tuff.

Microfloral Assemblage IV: Scollard Locality 1, Samples F to L; Zero to 42 feet above the Kneehills Tuff.

Scollard Locality 2, Samples E and D; 80 to 90 feet above the Kneehills Tuff.

Scollard Locality 18, Samples 10 to 8; 5 to 12 feet above the Kneehills Tuff.

Microfloral Assemblage III: Scollard Locality 1, Samples 1 to 16; zero to 45 feet below the Kneehills Tuff.

Microfloral Assemblage II: Scollard Locality 1, Samples 18, 19; 48 to 50 feet below the Kneehills Tuff.

Microfloral Assemblage I: Scollard Locality 1, Samples 24; 70 feet below the Kneehills Tuff.

Paleoecological Interpretations

Microfloral Assemblage I: The lowermost samples selected were in the upper part of the Middle Edmonton Member below the Whitemud beds and Sample 24 of Scollard Locality I was selected as representative. This sample, taken 70 feet below the Kneehills Tuff, yielded an abundant microflora of many species.

Bryophytes and pteridophytes are represented by the families Sphagnaceae, Polypodiaceae and abundant spores of the genus Schizosporis. Most of the members of Polypodiaceae require shade and humid climate.

The following cycad and conifer representatives are present: abundant cycadalean monosulcate pollen, split pollen of Cupressus and the Taxodiaceae, a few bisaccate pollen grains of the Podocarpaceae, Pityosporites, Phyllocladus, and Cedrus. In the present day floras, Cupressus is found in warm climates, Taxodium in swamps and along rivers, and Podocarpus in tropical to subtropical climates.

The angiosperm suite contains members of the following families: Myricaceae, Rhizophoraceae, Salicaceae, Aquifoliaceae (cf. Ilex) and Sapindaceae. The form genus Aquilapollenites dominates the microflora. Aquilapollenites is widely diverse pollen at the genus (or species) level whose probable affinities lie with the Santalaceae, Loranthaceae and Lythraceae (Funkhouser 1961; Stanley 1961; Khlonova 1962).

The total spore-pollen spectrum suggests the occurrence of families (or related families) that by modern distribution are found in a warm, humid, tropical climate. There is an indication of a luxurious angiospermic vegetation associated with an abundant bryophytic and pteridophytic undergrowth close to the site of deposition.

Much of the vegetation was in swamps and the pollen were not carried very far by wind.

The borderland of the source seems to be of elevated relief where coniferous vegetation existed and naturally a few grains of resistant pollen were received in the sediments after long distance wind transport.

Microfloral Assemblage II: Samples 19 and 18 of Scollard Locality 1 were selected from the upper part of the Middle Edmonton, immediately below the Whitemud beds and yielded a good variety of microflora. Drastic changes in the vegetational pattern are noted. A number of spores and pollen of the earlier beds are absent and many new ones are introduced.

Bryophytes and pteridophytes: Though most of the families listed in microfloral assemblage I are still represented, the genera are dissimilar. *Azolla* (family Salviniaceae) is present in great numbers along with its massulae and glochidia, etc. The Osmundaceae are absent and the Polypodiaceae have become the dominant element of the pteridophytes.

Cycads and conifers: Pollen grains referable to Taxodiaceae are abundant and bisaccate conifer pollen grains are also numerous. Abundant inaperturate pollen grains referred to *Larix* are present which were not recorded from assemblage I.

Angiosperms: A great change in the angiospermic microflora is seen. Pollen grains referable to *Aquilapollenites* are completely absent in Sample 19 while one new form i.e. *Aquilapollenites subtilis* Mtchedlishvili (Plate VIII, figs. 10-12) appears in Sample 18. A solitary grain of *Aquilapollenites* sp. (Plate IX, figs. 508, 10) reappears in Sample 18. *Alnus* and a tricolpate pollen cf. *Salix* also appear at this stage.

Assemblage I to II differ in part by slow evolution and through climatic changes. The abrupt change in the floral composition within such a short stratigraphic interval would suggest a new sere. Establishment of new elements suggests revolutionary events somewhere at a distance which changed the climatic conditions drastically to the extent that the earlier vegetation did not survive (of microfloral assemblage I) and new

forms suited to the climatic change were introduced.

Polypodiaceae is represented profusely along with a few more pteridophytic spores. Taxodium pollen are also received in large numbers which suggests a swampy locality. A few pollen of Sequoia and Salix are also represented.

Coniferous bisaccate pollen were received in the sediments, but these must be long distance transported as these are not dominant. Borderlands might be of high topography with corresponding cooler climate.

Presence of Azolla suggests deposition under local conditions in quiet stagnant pools or slowly moving water.

Sample 18 shows further decrease in pteridophytic spores. Only Polypodiaceae and Cyatheaceae is represented. Azolla has also disappeared. However, sediment continued to get a few coniferous bisaccate pollen in its deposition. Among angiosperms, Alnus, Aquilapollenites subtilis, tricolpate pollen appear and solitary pollen of Aquilapollenites sp. (loc. cit.) reappear. Larix pollen is also present which must have come from the low lying mountainous region.

In general the change from Microfloral Assemblage I to Assemblage II could be interpreted as reflecting a slight decrease in average temperature although both are tropical to warm subtropical.

Microfloral spectra of these two samples (18 and 19) reveal vegetational succession, near stagnant water bodies, under humid and a little cooler climate.

Microfloral Assemblage III: Samples 16 to 1 of Scollard Locality 1 represent the Whitemud and Blackmud beds of the Edmonton Formation. None of the samples examined yielded any spores or pollen grains. In as much as no hystrichospheres were noted, it would appear that in part this is a preservation phenomenon, although Warren and Stelck suggested in 1956 that these members were perhaps marine. Certainly the wide recognition of these members would suggest some extensive (brackish?) laking. The bentonitic contents of these two members may have been a destructive factor

especially in the surface beds.

The lack of spores and pollen grains makes it difficult to assess changes in ecology but in consideration of the cooler pattern indicated in the overlying beds, the following comments are appropriate.

The large content of bentonite in these beds suggests that the atmospheric content of volcanic dust would substantially decrease the total solar radiation reaching the earth's surface and eventually might have reduced temperatures somewhat. Recently Flowers and Viebrock (1965) noted a decrease of 5 to 78 percent in the normal intensity of the solar radiation at normal incidence at the South Pole and the causal factor believed is to be a layer of atmospheric dust resulting from recent volcanic eruptions. They examined the other factors, including an increase of extra-terrestrial material and rejected this as unlikely.

Microfloral Assemblage IV: Samples F to L (Scollard Locality 1), E and D (Scollard Locality 2), Samples 8, 9 and 10 (Scollard Locality 18) come from the beds immediately above the Kneehills Tuff and include the mammal localities of Scollard Locality 1 and 18. These beds yielded a lot of organic matter, and deformed, unidentifiable microspores along with a few coniferous bisaccate pollen which may have been transported long distances. However, Samples J of Scollard Locality 1 and Sample 10 of Scollard Locality 18 did yield a few spores of Polypodiaceae, triletes and a few monosulcates.

By the nature of the microspores recovered it seems that the mammal locality of Scollard Locality 1 (Samples J to L) and that of Scollard Locality 18 (Samples 10 to 8) belong to the same beds. It may be noted that in Scollard Locality 1, the mammal beds are about 35 feet above the Kneehills Tuff while in Scollard Locality 18 they are only about 6 to 7 feet above it. This suggests an erosional unconformity between the Kneehills Tuff and the mammal beds while the presence of the Blackmud beds below indicates regional laking or flooding.

Solitary and infrequent presence of microspores suggest that conditions had returned towards the establishment of a new sere but the conditions for preservation of microspores at the deposition site were not still very congenial. Bisaccate pollen which are of coniferous origin which may have been carried from a long distance, suggest cool climate at their source. Further, pteridophytic spores also support the existence of cool temperature conditions along with humidity.

This suite is introductory to Microfloral Assemblage V and seems to represent the reintroduction of fluvial or fluvio-deltaic conditions.

Microfloral Assemblage V: Observations are based on the yield of the Samples C_1, C, B, A, 5 and 6 of Scollard Locality 2. This represents the section of the Edmonton Formation above the mammal beds of Scollard Locality 1 and below the Ardley seam. In this zone microflora represent a rich angiospermic vegetation much changed from the vegetation recorded below the Whitemud beds.

Bryophytes and pteridophytes: Lycopodium sp. having large spores appears in these sediments. There were not many varieties of pteridophytes, but Polypodiaceae and Cyatheaceae are represented.

Cycads and conifers: There was a good representation of Cupressus and Taxodium. A few inaperturate pollen referable to Larix are also recovered. Coniferous bisaccate pollen continue to be present.

Angiosperms: A wide variety of angiospermic pollen recovered are referable to Oleaceae (cf. Fraxinus), Myrtaceae, Fagaceae (cf. Quercus), Rhizophoraceae, Platanus, Juglandaceae, Ericaceae, Magnoliaceae (cf. Liriodendron), Liliaceae, Loranthaceae (cf. Elytranthe). A new form of Aquilapollenites sp. (Plate IX, figs. 11-13), and angiospermic pollen, Tetracolpites and Polycolpites have also appeared.

Forms like Kryshtofoviana, whose affinity is not established, appear in this zone.

The microflora in this zone represents a rich prevalent angiospermic woodland

vegetation near the depositional site under whose shades many club mosses like *Lycopodium* were thriving. Tender plants of Liliaceae were also present. *Taxodium* and *Cupressus* were associated with this flora. This suggests a warm, humid, tropical climate with some subtropical aspects, such as decrease in pteridophytic variety, introduction of *Taxodium* and the spectrum of dicotyledonous flora more of subtropical aspect or even warm temperate (like that of Carolina).

Bisaccate coniferous pollen continued to be received from long distances, their source was probably high altitude with cooler climate to support the coniferous vegetation. Such a climate along with the vegetation discussed above was well established by the time when Samples 5 and 6 of Scollard Locality 2 were being deposited.

Significance of Reworked Microspores

All along in the sediments various eroded, deformed, indistinct morphologically microspores are recovered. The superficial features of these forms indicate Paleozoic origin. This suggests that during the deposition, sediments were received from a source which was also (partly at least) of Paleozoic age (Rising Cordilleran source?).

Summary

Five Microfloral Assemblages are delineated on the basis of the microspore spectra constructed on the microfossils recovered from the Scollard Localities 1, 2 and 18. Five ecological breaks or changes may also be associated with them.

Throughout Microfloral Assemblage I, it is indicated that a rich swamp forest was standing along the site of deposition, supporting a variety of Bryophytes, pteridophytes, *Taxodium* and many angiospermic families suggesting warm, humid, tropical climate. Bordering such a vegetation there might be at some distance podocarpaceous and *Cupressus* vegetation. Other coniferous vegetation might be

supported at a farther distance in a cooler climate probably at higher altitude.

Some revolutionary events took place somewhere at a distance which changed the climatic conditions abruptly and the rich established vegetation was destroyed almost completely. The first part of the Microfloral Assemblage II i.e. the microspore spectrum of Sample 19 of Scollard Locality 1, shows the first phases of the establishment of hydrosere stages which changed towards a swampy type of sere during the deposition of Sample 18 of Scollard Locality 1.

Sediments increase in volcanic ash content during Microfloral Assemblage III and preservative conditions were not congenial hence no microspores were recovered. The ash content increased with the Kneehills Tuff beds representing the maximum.

Above the Kneehills Tuff beds an erosional unconformity is indicated. In Scollard Locality 1, mammal beds are about 35 feet above the Kneehills Tuff while in Scollard Locality 18, these are 6 feet above the Kneehills Tuff. This unconformity regionally cuts into the Blackmud beds which in themselves represented a still stand of laking or marine invasion.

The preservative conditions of the microspores were not very good for Microfloral Assemblage IV, but the depauperate microflora preserved shows the establishment of a sere of a cooler climate which became warmer again somewhat later.

Microfloral Assemblage V shows the restoration of a rich vegetational stand, starting with initial stages of woodland vegetation and reaching maturity in its establishment. Vegetation supported indicates tropical climate with some subtropical aspects and introduction of dicotyledonous flora with more of a subtropical to warm temperate aspect.

Ecological Summary

(1) Initially the swampy vegetation of tropical, humid climate was destroyed and then was established sere of a cooler climate, before the Whitemud beds were laid

down. Then above the Kneehills Tuff at the mammal-bed horizon a microflora of a still cooler climate appears which gave way to warmer subtropical to warm temperate flora as the Ardley coal seam depositional sequence is approached.

(2) The lithologies indicate that there was an increase in volcanic ash fall throughout the Whitemud and Blackmud sequence reaching a maximum at the Kneehills Tuff. The temperature indicated above and below the Blackmud and Whitemud beds is assumed to have lowered to a minimum during the time of deposition of these beds, and may be due to the decrease in the solar radiation by the volcanic ash in the atmosphere at that time.

(3) The sediments below the Whitemud beds seen to be in large measure fluvial and a lowering of gradient (or rise in sea level) resulted in laking (or flooding) during Blackmud time. Re-uplift occurred (or increase in gradient) after Blackmud time to produce some erosional phenomena at the upper Blackmud contact. Subsequent lowering of the gradient finally reproduced the coal swamps of the Ardley coal sequence.

The scarcity of mammal remains in the later parts of the upper Edmonton and in the pre-Whitemud beds may indicate that the mammals appeared as a foreshadowing of the Tertiary in a temporary period of cooling, the early Lance time.

Age and Correlation

The microfloras recovered compare well with the Upper Cretaceous microflora reported from North America and Russia, references to which have already been made under the review of the palynological work done. The assemblage is particularly comparable with those recorded as Maestrichtian Age in North America. The prolific presence of many species of Aquilapollenites and genus Kryshtofoviana (= Wodehouseia Stanley) along with a host of pteridophitic spores and angiospermic pollen are characteristic of late Upper Cretaceous.

A few genera identified as Sequoiapollenites, Tricolpites and Fraxinoipollenites

may have close affinity to the genera Sequoiites, Platanus and Fraxinus recorded by Bell (1949) from the Edmonton Formation on which basis Bell correlated with the Lance Formation. Microfossils described here and megafossils described by Dorf (1938, 1940, 1942) from the Lance Formation show relationships with Salviniaceae, Magnoliaceae, Quercus, Salix, and Myrtaceae.

CHAPTER FIVE

PALYNOLOGIC TAXONOMY

Potonie's (1956, 1958, 1960) morphologic system of classification has been used at the generic and specific level. Genera which could be associated and assigned with families have been grouped under them to show inter-relationship. The principles of priority and type method have been followed. Some pollen types which could be referred to natural genera but need more confirmation are referred to that genus.

FORMAL DESCRIPTIONS

FAMILY SPHAGNACEAE

Genus Sphagnumsporites Raatz, 1937

1934 Sporites stereoides Potonie and Venitz, Arb. Inst. Palaobot. Petrogr. Brennsteine, vol. 5, p. 11, pl. I, fig. 4.

1937 Sphagnumsporites Raatz, Abhandl. Preuss. Geol. L. A. (Berlin), n. F., Heft 183, p. 9.

1953 Stereisporites Pflug, Palaeontographica, Band 94, Abt. B, p. 53.

1953 Sphagnites Cookson, Australian J. Bot., vol. 1, p. 463, pl. 1, figs. 1-4.

1956 Sphagnumsporites stereoides (Potonie and Venitz) Potonie, Beih. Geol. Jb., Heft 23, p. 17 (type species).

DIAGNOSIS: Trilete, laesurae simple, reaching the equator in some species, size small, equatorial outline triangular with convex sides, corners rounded, arched in some species, exine smooth, relatively thick and rigid.

Sphagnumsporites antiquasporites (Wilson and Webster, 1946) Pocock, 1962
Plate I, figures 1-3

1946 Sphagnum antiquasporites Wilson and Webster, Am. J. Bot., vol. 33, p. 271-278.

1947 Triletes australis Cookson, B. A. N. Z. Antarctic Res. Expedition, Rept. A 2, p. 136, pl. 15, figs. 58, 59.

1953 Sphagnites australis Cookson, Australian J. Bot., vol. 1, p. 463, pl. 1, figs. 1-4.

1959 Sphagnum punctaesporites Rouse, Micropaleont., vol. 5, p. 308, pl. 1, figs. 25-28.

1962 Sphagnumsporites antiquasporites (Wilson and Webster) Pocock, Palaeontographica, Band 111, Abt. B, p. 32, pl. I, figs. 1-3.

DESCRIPTION: Trilete, laesurae simple, from 1/2 to 2/3 of radius of spore, equatorial outline triangular with strongly convex sides, corners rounded, arcuate thickenings subtend the angles of the laesurae, one micron wide, thickened zone around the equator, exine smooth.

SIZE: Equatorial diameter 20 to 24 microns.

FIGURED SPECIMEN:

Plate I,	Figure 1	Sc 2 - C/1	32.8/123.1
	Figure 2	Sc 1 - 24/1	40.5/108.2
	Figure 3	Sc 1 - 24/1	21.1/119.5

Sphagnumsporites sp.

Plate I, figures 4, 5.

DESCRIPTION: Trilete, laesurae simple, long with wavy and parallel lips reaching the equatorial margin, equatorial outline triangular with strongly convex sides, corners rounded, exine smooth.

SIZE: Equatorial diameter 22 to 30 microns.

FIGURED SPECIMEN:

Plate I,	Figure 4	Sc 1-24/1	44.4/114.9
	Figure 5	Sc 1-24/1	36.2/128.3

Sphagnumsporites sp.

Plate I, figures 6, 7.

DESCRIPTION: Trilete, laesurae simple, long, reaching equatorial margin, equatorial outline triangular with strongly covex sides, corners rounded, arcuate thickenings subtent the angles of the laesurae and extend up to the margin, exine moderately verrusose, exine thickness 1 to 2 microns.

SIZE: Equatorial margin 30 to 34 microns.

FIGURED SPECIMEN:

Plate I,	Figure 6	Sc 1-24/1	46.5/108.8
	Figure 7	Sc 1-24/1	64.2/127.5

FAMILY CYATHEACEAE

Genus Cyathidites Couper, 1953

1953 Cyathidites australis Couper, New Zealand Geol. Surv. Paleont. Bull. 22, p. 27, pl. 2, figs. 11, 12.

DIAGNOSIS: Free, anisopolar, trilete, laesurae clearly defined, long, always over two-thirds of the radius of the spore. Spores triangular, apices broadly rounded and sides concave between apices in polar view. Both proximal and distal surfaces convex, distal markedly so. Exine psilate.

Cyathidites cf. C. minor Couper, 1953

Plate I, figures 8-10

1953 Cyathidites minor Couper, New Zealand Geol. Surv. Paleont. Bull. 22, p. 28, pl. 2, fig. 13.

DESCRIPTION: Free, anisopolar, trilete, laesurae distinct, long. Spores triangular to sub-triangular, apices very broadly rounded and sides concave in polar view. Exine psilate, about 1.5 microns thick, delicate and crumbles at many places.

SIZE: Equatorial diameter 30 to 46 microns.

FIGURED SPECIMENS;

Plate I,	Figure 8	Sc 1-24/1	64.5/114.0
	Figure 9	Sc 1-24/3	54.0/115.4
	Figure 10	Sc 2- 5/2	65.5/119.0

FAMILY GLEICHENIACEAE

Genus *Gleicheniidites* (Ross, 1949) Del. and Sprum., 1955

1949 *Gleicheniidites senonicus* Ross, Bull. Geol. Inst. Upsala, vol. 34, p. 31, pl. 1, figs. 3, 4 (type species).

1955 *Gleicheniidites senonicus* (Ross) Del. and Sprum., Mem. Soc. Belg. Geol., n.s., vol. 5, p. 26 (Designation of type and generic diagnosis).

DIAGNOSIS: Trilete, laesurae simple, reaching equator, equatorial outline triangular, sides straight or slightly concave, apical angles arched.

Gleicheniidites senonicus Ross, 1949

Plate I, figures 11-13

1949 *Gleicheniidites senonicus* Ross, Bull. Geol. Inst. Upsala, vol. 34, p. 31, pl. 1, figs. 3, 4.

1957 *Gleichenia concavisporites* Rouse, Can. J. Bot., vol. 35, p. 363, pl. 2, figs. 36 and 48, pl. 3, fig. 49.

DESCRIPTION: Trilete, laesurae long, reaching the equator, polar view triangular, sides usually straight but sometimes concave, apical angles generally fairly sharp, proximal face flattened, distal face convex, exine smooth or slightly granular, about 1 to 1.5 microns thick.

SIZE: Equatorial diameter 28 to 36 microns.

FIGURED SPECIMEN:

Plate I,	Figure 11	Sc 1-24/1	61/119
	Figure 12	Sc 1-24/3	55.1/109.4
	Figure 13	Sc 1-24/1	55/122.5

FAMILY OSMUNDACEAE

Genus Osmundacidites Couper, 1953

1953 Osmundacidites wellmanii Couper, New Zealand Geol. Surv. Paleont. Bull. 22, p. 20, pl. 1, fig. 5 (type species).

DIAGNOSIS: Free, anisopolar, trilete, laesurae moderately long, spores spherical to subspherical. Exine thin, granular, papillate, sculpture somewhat reduced on proximal face.

Osmundacidites wellmanii Couper, 1953

Plate I, figure 20, plate II, figure 1.

1953 Osmundacidites wellmanii Couper, New Zealand Geol. Surv. Paleont. Bull. 22, p. 20, pl. 1, fig. 5.

DESCRIPTION: Trilete, laesurae simple, moderately long, exine thin, granular papillate, with reduced sculpture on proximal face.

SIZE: Equatorial diameter 46 to 52 microns.

FIGURED SPECIMEN:

Plate I, Figure 20	Sc 1-24/3	25.8/120.4
Plate II, Figure 1	Sc 1-24/2	70.6/108.6

Osmundacidites elongatus (Rouse) new combination

Plate II, figures 2, 3.

1957 Osmundasporites elongatus Rouse, Can. J. Bot., vol. 35, p. 362, pl. III, figs. 59, 60.

DESCRIPTION: Trilete, elongately elliptical in shape, laesurae weak, generally obscured by folding or compression. Ornamentation granular papillate, individual papillae thicker, exine thin.

SIZE: 46 to 63 microns

FIGURED SPECIMEN:

Plage II, Figure 2	Sc 1-24/1	59.6/112.3
Figure 3	Sc 1-24/3	67.7/109.3

FAMILY LYCOPODIACEAE

Genus Lycopodiumsporites Thiergart, 1938 ex Delcourt & Sprumont, 1955

1934 Sporites agathoecus Potonie, Arb. Inst. Palaobot. Petrogr. Brennsteine, vol. 4, p. 43, pl. 1, fig. 25.

1938 Lycopodiumsporites agathoecus (Potonie) Thiergart, Jahrb. Preuss. Geol. L. A. (Berlin) (1937), vol. 58, p. 293, pl. 22, figs. 9, 10 (type species).

DIAGNOSIS: Trilete, equatorial outline subtriangular, laesurae reaching equator in some species, distal surface reticulate with regular muri, muri high in some specimens, proximal surface usually unsculptured.

Lycopodiumsporites vermiculaesporites (Rouse, 1957) new combination

Plate II, figure 4

1957 Lycopodium vermiculaesporites Rouse, Can. J. Bot., vol. 35, p. 361-362, pl. III, figs. 73, 74.

DESCRIPTION: Trilete, circular to oblongate in shape, laesurae extending up to the periphery. Ornamentation vermiculate. On proximal surface ornamentation is less, exine moderately thin.

SIZE: 34 to 40 microns.

FIGURED SPECIMEN:

Plate II, figure 4 Sc 1-24/1 57/114.3

Lycopodiumsporites papillaesporites (Rouse, 1957) new combination

Plate II, figures 6-8

1957 Lycopodium papillaesporites Rouse, Can. J. Bot., vol. 35, p. 361, pl. III, fig. 50-52.

DESCRIPTION: Trilete, broadly subtriangular in shape, laesurae simple, extending to the periphery. A thin hyaline perispore surrounds the spore. Ornamentation reticulate, with thin papillae extending from the reticulum, papillae about five microns long.

SIZE: 42 to 48 microns

FIGURED SPECIMEN:

Plate II,	figure 6	Sc 1-24/1	47.8/109.7
	figure 7	Sc 1-24/1	51.0/112.2
	figure 8	Sc 1-C/14	58.4/123.6

Lycopodiumsporites sp.

Plate II, figures 9-12

DESCRIPTION: Trilete, laesurae long, distal surface has thick and broad reticulate pattern. Muri strong, raised, lumina about 12 to 18 microns wide. Perispore has long thicker strands of different lengths, strands are granular in structure. Perispore seems loose and weakly attached because it comes off easily from the body. Proximal side is without reticulate structure. Inner body has fine reticulate pattern which is distinctly visible when perispore is detached.

SIZE: 80 to 95 microns

REMARKS: Many spores are recovered with complete perispore, some with partial, and others without any perispore. The exact similarity in the arrangement of the laesurae, exine structure of the body and size suggest their being of the same species. Gradation of differential perispore covering is shown in figures 9-12 (Plate II).

FIGURED SPECIMEN:

Plate II,	figure 9	Sc 2-C_1/2	46.5/110.0
	figure 10	Sc 2-C_1/2	43.7/116.8
	figure 11	Sc 2-C_1/1	69.8/122.2
	figure 12	Sc 2-C_1/1	25.5/122.2

FAMILY SCHIZAEACEAE

Genus Lygodioisporites Potonie, 1951 emended Singh, 1964

1934 Sporites solidus Potonie, Arb. Inst. Palaobot. Petrogr. Brennsteine, vol. 4, p. 42, pl. 1, fig. 35.

1951 Lygodioisporites solidus (Potonie) Potonie, Palaeontographica, vol. 91, Abt. B, p. 144, pl. 20, figs. 12, 13 (type species, subsequent designation.)

1953 Corrugatisporites solidus (Potonie) Thomson and Pflug, Palaeontographica, vol. 94, Abt. B, pl. 2, figs. 37, 38, 40-43.

DIAGNOSIS: Trilete, laesurae extending from 1/2 to 4/5 of the spore radius, equatorial outline triangular with strongly convex to nearly straight sides and well-rounded apices, ornamentation consisting of irregularly arranged, coarse, intersecting rounded ridges with projecting tubercles running in radial or other directions, spherical verrucae which may be dense or sparse or confluent tubercles.

Lygodioisporites sp.

Plate III, figure 2

DESCRIPTION: Trilete, laesurae long, reaching equatorial margin, equatorial outline triangular with slightly convex sides and rounded apices, ornamentation verrucate, verrucae about 2 to 3 microns wide, spherical and dense on the surface.

SIZE: Equatorial diameter 36.4 microns.

FIGURED SPECIMEN:

Plate III, figure 2 Sc 1-24/3 25.8/129.1

FAMILY SALVINIACEAE

Genus Azolla Lamark, 1783

Azolla sp. cf. A. primaeva (Penhallow) Arnold

Plate III, figures 12-15

DESCRIPTION: Trilete, circular to roundly subtriangular in equatorial contour, narrow laesurae reaching half way to the equatorial margin, a narrow distinct

margo in the angles of the laesurae, ornamentation finely and strongly punctate, wall thickness about two microns.

SIZE: 31.2 microns

REMARKS: Plate III, figure 13 shows a massula of Azolla with a microspore inside it. Plate III, figure 14 shows many glochidia on the massula wall and figure 15 of Plate III shows glochidium magnified under high power.

FIGURED SPECIMEN:

Plate III,	figure 12	Sc 1-19/1	72.8/115.5
	figure 13	Sc 1-19/3	43.5/129
	figure 14	Sc 1-19/2	59.6/123.4
	figure 15	same as figure 14.	

FAMILY POLYPODIACEAE

Genus Polypodiidites Ross ex Couper, 1953

1949 Polypodiidites senonicus Ross, Bull. Geol. Inst. Upsala, vol. 34, p. 33, pl. 1, figs. 8, 9 (type species).

1953 Polypodiidites perverrucatus Couper, New Zealand Geol. Surv. Paleont. Bull. 22, p. 29, pl. 2, figs. 17, 18.

DIAGNOSIS: Monolete, free, anisopolar, bilateral, exine thick, sculpture sub- to per-verrucate.

Polypodiidites perverrucatus Couper, 1953

Plate IV, figures 8, 10

1953 Polypodiidites perverrucatus Couper, New Zealand Geol. Surv. Paleont. Bull. 22, p. 29, pl. 2, figs. 17, 18.

DESCRIPTION: Monolete, free, anisopolar, bilateral, laesurae almost equal to the length of the spores, more or less plano-convex in lateral view, exine thick, about 2.5 microns, verrucae very closely placed and sometimes are not well separated or pronounced and give reticulate ornamentation in different foci.

SIZE: 46.8 to 62.4 by 33.8 to 44 microns

FIGURED SPECIMEN:

Plate IV, figure 8 Sc 1-19/2 66.8/128.8

figure 10 Sc 2- 5/2 29/121.4

Polypodiidites sp.

Plate IV, figures 9, 11

DESCRIPTION: Monolete, free, anisopolar, bilateral, suture almost half the length of the spores, more or less plano-convex or elliptical, exine thick, pronounced reticulate ornamentation.

SIZE: 57.2 to 59.8 by 39 to 44 microns

FIGURED SPECIMEN:

Plate IV, figure 9 Sc 1-24/2 28.3/113.4

figure 11 Sc 1-19/3 66.4/114.0

ORDER FILICALES - INCERTAE SEDIS

Genus Punctatisporites (Ibrahim, 1933) Potonie and Kremp, 1955

1932 Punctatisporites punctatus Ibrahim in Potonie, Ibrahim and L., p. 448, Taf. 15, fig. 18.

DIAGNOSIS: Trilete, exine punctate.

Punctatisporites sp.

Plate I, figure 14

DESCRIPTION: Trilete, spore small, folded, lens-like equatorial contour, laesurae very small and simple, closed, exine punctate.

SIZE: 31.2 by 23.5 microns

FIGURED SPECIMEN:

Plate I, figure 14 Sc 1-19/1 51.8/129.0

Genus Deltoidospora (Miner) Potonie, 1956

1935 Deltoidospora hallii Miner, Am. Mid. Nat., vol. 16, no. 4, p. 618, pl. 24, figs. 7, 8.

1956 Deltoidospora hallii Miner in Potonie, Beih. Geol. Jb., vol. 23, p. 23, p. 13, pl. 1, fig. 1 (assignment of genotype).

DIAGNOSIS: Trilete, equatorial outline triangular, apices more or less rounded, exine smooth, laesurae simple and over 2/3 radius of the spore.

Deltoidospora psilotoma Rouse, 1959

Plate I, figure 15

1959 Deltoidospora psilotoma Rouse, Micropaleont., vol. 5, p. 311, pl. 12, figs. 7, 8.

DESCRIPTION: Trilete, laesurae over 2/3 radius of spore, commissures simple, frequently gaping, equatorial contour triangular with straight to slightly concave or convex sides, apical angles well rounded, exine laevigate to punctate.

SIZE: Equatorial diameter ca. 44 microns

FIGURED SPECIMEN:

Plate I, figure 15 Sc 1-24/2 44.7/113.3

Deltoidospora hallii Miner, 1935

Plate I, figure 16

1935 Deltoidospora hallii Miner, Am. Mid. Nat., vol. 16, no. 4, p. 618, pl. 24, figs. 7, 8.

DESCRIPTION: Trilete, laesurae over 2/3 total diameter, simple, equatorial contour triangular, sides usually slightly concave, sometimes straight, exine smooth, thin.

SIZE: Equatorial diameter ca. 32 microns.

FIGURED SPECIMEN:

Plate I, figure 16 Sc 1-24/1 41.6/115.2

<u>Deltoidospora</u> sp.

Plate I, figure 17

DESCRIPTION: Trilete, broken triangular opening in the center and laesurae meet towards the equatorial margin at about 2/3 length, exine thickened around trilete opening, exine about one micron thick and smooth. Ornamentation infra-punctate.

SIZE: Equatorial diameter ca. 38 microns

FIGURED SPECIMEN:

Plate I, figure 17 Sc 1-24/1 37.5/108.6

Genus <u>Concavisporites</u> Pflug, 1953

1953 <u>Concavisporites</u> <u>regulatus</u> Pflug, Palaeontographica,vol. 94 B, p. 49, pl. I, figs. 22.

DIAGNOSIS: Trilete microspores with margo developed, equatorial contour triangular, sides more or less concave.

<u>Concavisporites</u> <u>acutus</u> Pflug, 1953

Plate I, figures 18, 19

1953 <u>Concavisporites</u> <u>acutus</u> Pflug, Palaeontographica, vol. 94 B, p. 49, pl. I, figs. 25-29.

DESCRIPTION: Trilete, laesurae simple, extend up to the equatorial margin, spores triangular with concave sides and rounded apical lobes, exine about one micron thick and punctate.

SIZE: Equatorial diameter 28 to 32 microns.

FIGURED SPECIMEN:

Plate I, figure 18 Sc 1-24/1 71/118.9

figure 19 Sc 1-24/1 33.8/127.7

Genus Ceratosporites Cookson and Dettmann, 1958

1958 Ceratosporites equalis Cookson and Dettmann, Proc. Roy. Soc. Victoria, n.s., vol. 70, p. 101, pl. 14, figs. 17-20, (type species for genus).

DIAGNOSIS: Spore tetrahedral, trilete, distal surface ornamented by blunt or sharply pointed processes, proximal surface smooth.

Ceratosporites sp.

Plate II, figure 5

DESCRIPTION: Spores tetrahedral, trilete, almost subtriangularly oval in polar view, laesurae extending to the margin. Exine thin, proximal surface unornamented, distal surface with very closely spaced, thin, straight-sided, blunt, capitate, slightly or occasionally slightly bifurcate processes.

SIZE: Equatorial diameter 36.4 microns

FIGURED SPECIMEN:

Plate II, figure 5 Sc 1-24/3 67.7/110.2

Genus Baculatisporites Thomson and Pflug, 1953

1953 Baculatisporites (al. Sporites) primarius (Wolff 1934, p. 66, Taf. 5, fig. 8, Zeichnung nach Prap XVI 50 in Berlin) Thomson and Pflug, Palaeontographica, vol. 94 B, p. 56 (type species for genus).

1953 Triletes comaumensis Cookson, Australian J. Bot., vol. I, no. 3, p. 470, pl. 2, figs. 27-28.

1953 Baculatisporites primarius (Wolff) Thomson and Pflug, Palaeontographica, vol. 94 B, p. 56, Taf. 2, figs. 49-53.

DIAGNOSIS: Trilete spore, laesurae long, reaching equatorial margin, equatorial contour more or less spherical, exine thin and closely ornamented with blunt rod-like processes.

Baculatisporites sp. cf. B. commaumensis (Cookson, 1953) Potonie, 1956

Plate II, figure 13

Syn. as for the genus.

DESCRIPTION: Spores more or less spherical, laesurae extending to the equatorial periphery, wall thin, ornamented with blunt rod-like processes about two microns long.

SIZE: 52 microns

FIGURED SPECIMEN:

Plate II, figure 13 Sc 1-24/2 38/118.0

Genus Microreticulatisporites (Knox, 1950) Potonie and Kremp, 1954

1933 Reticulatisporites lacunosus Ibrahim, Sporenformen des Aegirhorizonts, p. 36, pl. 6, fig. 50 (type species).

1950 Microreticulati-sporites lacunosus (Ibrahim) Knox, Trans. Bot. Soc. Edinb., p. 320, pl. 18, fig. 240.

1954 Microretculatisporites lacunosus (Knox) Potonie and Kremp, Palaeontographica, vol. 98, Abt. B, p. 96, figs. 24-25.

DIAGNOSIS: Trilete, equatorial outline triangular to circular, exine reticulate with small lumina of about six microns, muri may be imperfect and branched.

Microreticulatisporites sp.

Plate III, figure 1

DESCRIPTION: Trilete, broadly subtriangular to round in shape, simple laesurae not very clear in the spore due to the heavy ornamentation which is reticulate, with short papillae coming out of the reticulum. Ornamentation much heavier on the distal side.

SIZE: 39 microns

FIGURED SPECIMEN:

Plate III, figure 1 Sc 1-24/1 41.4/127.6

Genus Verrucosisporites Ibrahim, 1933, emended Potonie and Kremp, 1954

1932 Sporites verrucosus Ibrahim, in Potonie, Ibrahim and Loose, Neues Jahrb. Mineral., Geol. Palaont., vol. 67, Abt. B, p. 448, pl. 15, fig. 17.

1933 Verrucosi-sporites verrucosus Ibrahim, doctor. diss. Tech. Hochschule zu Berlin (privately published), p. 25, pl. 2, fig. 17.

1955 Verrucosisporites verrucosus Ibrahim, emended Potonie and Kremp, Palaeontographica, vol. 98, Abt. B, p. 69, pl. 13, fig. 196 (type species).

DIAGNOSIS: Trilete, circular to subcircular in equatorial outline, exine covered with thickly-crowded broad-based warts more or less irregularly rounded or in some cases arcuate.

Verrucosisporites asymmetricus (Cookson and Dettmann, 1958) Pocock, 1962

Plate III, figures 3-5

1958 Apiculatisporites asymmetricus Cookson and Dettmann, Proc. Roy. Soc. Victoria, n.s., vol. 70, pt. 2, p. 100, pl. 14, figs. 11, 12.

1962 Verrucosisporites asymmetricus (Cookson and Dettmann) Pocock, Palaeontographica, vol. 111, Abt. B, p. 56, pl. 8, figs. 124-126.

DESCRIPTION: Trilete, laesurae indistinct, almost reaching the margin, equatorial outline variable, subtriangular to subcircular, sides invariably convex, exine about 2 to 3 microns thick, ornamented on both the distal and proximal surfaces by irregularly shaped flat-topped verrucae.

SIZE: Equatorial diameter 39 to 42 microns

FIGURED SPECIMEN:

Plate III,	figure 3	Sc 1-24/1	47.5/111.6
	figure 4	Sc 1-24/1	64.0/112.6
	figure 5	Sc 1-24/1	49.4/111.9

Genus Pilosisporites Delcourt and Sprumont, 1955

1949 Sporites trichopapillosus Thiergart, Palaeontographica, vol. 89, Abt. B, p. 22, pl. 4, fig. 18.

1955 Pilosisporites Trichopapillosus (Thiergart) Delcourt and Sprumont, Mem. Soc. Geol. Belgique, n.s., vol. 4, p. 34, pl. 3, fig. 3 (type species).

1961 Lygodium trichopapillosus (Thiergart) Bolkhovitina, Trudy. Geol. Inst. Akad. Nauk SSSR, vol. 40, p. 102, pl. 38, figs. 1a, b.

DIAGNOSIS: Trilete, laesurae do not reach the equator, equatorial contour triangular, sides slightly convex, straight or concave, ornamentation echinate, fimbriae, capilli or short thin spines cover all or large parts of the surface.

Pilosisporites sp.

Plate III, figure 6

DESCRIPTION: Trilete, laesurae more than 1/2 of radius of the equatorial contour, which is triangular with rounded apices and concave sides, thin slightly-knobbed small spines very closely spaced all over the surface of the exine. Exine thin.

SIZE: Equatorial diameter 52 microns

FIGURED SPECIMEN:

Plate III, figure 6 Sc 2-C/15 36.4/108.1

Genus Acanthotriletes Naumova, 1937 ex. Potonie and Kremp, 1954

1937 Acanthotriletes Naumova, Intern. Geol. Congr., 17th, Moscow, Absts. Papers, p. 60-61.

1950 Spinoso-sporites ciliatus Knox, Trans. Proc. Bot. Soc. Edinburgh, p. 313, pl. 17, fig. 206.

1954 Acanthotriletes ciliatus (Knox) Potonie and Kremp, Palaeontographica, vol. 98, Abt. B, p. 83, pl. 14, fig. 257 (type species).

DIAGNOSIS: Trilete, ciliate, spines closely crowded, attenuate, length of the spines greater than twice the diameter of their base.

Acanthotriletes sp.

Plate III, figure 7

DESCRIPTION: Trilete, laesurae extending to the margin. Equatorial contour of the spore triangular with rounded apices, sides slightly convex. Spines have a broad base and curved pointed tips, length of the spines more than double the breadth of their base. Spines closely spaced.

SIZE: Equatorial diameter 36.4 microns

Size of the spines 5.2 by 2 microns

FIGURED SPECIMEN:

Plate III, figure 7 Sc 1-24/3 51.8/130.0

Genus Undulatisporites Pflug in Thomson and Pflug, 1953

1953 Undulatisporites microcutis Pflug in Thomson and Pflug, Palaeontographica, vol. 94, Abt. B, p. 52, Taf. I, fig. 81.

DIAGNOSIS: Trilete, equatorial contour triangularly rounded. Exine irregularly undulate.

Undulatisporites sp.

Plate III, figure 8

DESCRIPTION: Trilete, equatorial contour triangular with rounded apices and slightly convex sides, laesurae have thickened wavy margo reaching equatorial margin, exine irregularly undulate.

SIZE: Equatorial diameter 39 microns

FIGURED SPECIMEN:

Plate III, figure 8 Sc 1-24/3 59.7/119.5

Genus Staplinisporites Pocock, 1962

1957 Cingulatisporites caminus Balme, Australia, C.S.I.R.O., Coal Res. Sect., Ref. T.C. 25, p. 27, pl. 5, figs. 62, 63.

1962 Staplinisporites caminus (Balme) Pocock, Palaeontographica, vol. III, Abt. B, p. 49, pls. 5, 6, figs. 87-90 (type species).

DIAGNOSIS: Trilete, well-developed raised commissures, equatorial outline rounded-triangular, proximal exine thin, smooth to granulose, distal surface ornamented by concentric and radial bands of exinal thickening, the distal pole carrying a thickened granulose boss which may become detached, leaving a thin granulose area.

Staplinisporites sp.

Plate III, figure 9

DESCRIPTION: Trilete, laesurae about 2/3 of the equatorial diameter, commissures raised and well developed, equatorial outline almost rounded, proximal exine thin, thin concentric bands of about 8 microns wide present, light, granular distal area present.

SIZE: Equatorial diameter 54.6 microns

FIGURED SPECIMEN:

Plate III, figure 9 Sc 1-24/1 42/109.3

Genus Triplanosporites Pflug in Thomson and Pflug, 1953

1953 Triplanosporites sinuosus Pflug in Thomson and Pflug, Palaeontographica, p. 58, Taf. 3, fig. 7.

DIAGNOSIS: Trilete, laesurae not distinct, equatorial contour extremely concave and three-plane lobed. Polar axis longer than equatorial diameter. Trilete mark sunk in the concavity, exine smooth.

Triplanosporites sp.

Plate III, figure 10

DESCRIPTION: Trilete, laesurae indistinct, equatorial contour triplaned and sides extremely concave making apices flap-like, polar axis is almost equal to the equatorial diameter, exine slightly punctate, and thin.

SIZE: 41.6 by 44 microns

FIGURED SPECIMEN:

Plate III, figure 10 Sc 1-19/1 45.3/120.3

Genus Camarozonosporites (Pant, 1954) ex Potonie, 1956

1953 Rotaspora cretaceous Wayland and Krieger, Palaeontographica, vol. 95, Abt. B, p. 12, Taf. 3, fig. 27.

1956 Camarozonosporites cretaceous (Wayland and Krieger, 1953) Potonie, Beih. Geol. Jb., vol. 23, p. 65, Taf. 9, fig. 85.

DIAGNOSIS: Trilete, equatorial contour rounded, cingulum of about 4 to 5 microns thick around the equatorial plane.

Camarozonosporites sp.

Plate III, figure 11

DESCRIPTION: Trilete, equatorial contour rounded, laesurae small. Opposite to the tips of the laesurae, exine corners are thickened. Exine smooth, ornamentation punctate.

SIZE: Equatorial diameter 31.2 microns

FIGURED SPECIMEN:

Plate III, figure 11 Sc 1-24/3 57.5/114.2

Genus Laevigatosporites Ibrahim, 1933 emended Schopf, Wilson and Bentall, 1944

1932 Sporonites vulgaris Ibrahim in Potonie, Ibrahim and Loose, Neues Jahrb. Mineral., Geol. Palaont., vol. 67, Abt. B, p. 448, pl. 15, fig. 16.

1933 Laevigato-sporites vulgaris (Ibrahim) Ibrahim, doctor. diss., Tech. Hochschule zu Berlin (privately published) p. 39-40, pl. 2, fig. 16 (type species).

1934 Laevigato-sporites vulgaris forma major Loose, Arb., Inst. Palaobot. Petrogr. Brennsteine, vol. 4, p. 158, pl. 7, fig. 12.

1945 Laevigato-sporites Ibrahim, emended Schopf et al, Illinois State Geol. Surv., Rept. Invest. 91, p. 36, pl. I, figs. 5, 5b.

1950 Laevigato-sporites ovalis Kosanke, Illinois State Geol. Surv. Bull. 74, p. 29, pl. 5, fig. 7.

DIAGNOSIS: Monolete, outline smooth, laevigate to infrapunctate, equatorial outline ovoid, meridional outline bean-shaped, exine without sculpture, monolete mark straight.

Laevigatosporites albertensis Rouse, 1957

Plate III, figure 16

1957 Laevigatosporites albertensis Rouse, Can. J. Bot., vol. 35, p. 363-364, pl. 11, figs. 17, 18.

DESCRIPTION: Monolete, kidney-shaped, suture weakly defined and always occurring along the concave crest. Ornamentation very finely punctate, exine margin smooth.

SIZE: 31.2 by 20.8 microns

FIGURED SPECIMEN:

Plate III, figure 16 Sc 1-24/1 32.4/119.1

Laevigatosporites discordatus Pflug in Thomson and Pflug, 1953

Plate III, figure 17; Plate IV, figure 1

1953 Laevigatosporites discordatus Pflug in Thomson and Pflug, Palaeontographica, vol. 94, Abt. B, p. 59, Taf. 3, figs. 40-43.

DESCRIPTION: Monolete, outline oval or little concave at the side of the lete, ornamentation infrapunctate, exine thin and smooth.

SIZE: 65 to 70.5 by 44 to 46.8 microns

FIGURED SPECIMEN:

Plate III, figure 17 Sc 2-C_1/1 36.4/125.3

Plate IV, figure 1 Sc 1-19/1 40.2/128.9

Laevigatosporites ovatus Wilson and Webster, 1946

Plate IV, figures 3, 4

1946 Laevigatosporites ovatus Wilson and Webster, Am. J. Bot., vol. 33, p. 273, fig. 5.

DESCRIPTION: Monolete, suture straight about 1/2 of the spore length, mostly gaping, outline kidney-shaped, exine shows very faint reticulate ornamentation.

SIZE: 49 to 52 by 34 to 41 microns

FIGURED SPECIMEN:

Plate IV, figure 3 Sc 1-19/2 58.4/128.5

figure 4 Sc 1-19/3 63.3/129.5

Laevigatosporites sp.

Plate IV, figure 2

DESCRIPTION: Monolete, suture at the concave side, closed, kidney-shaped outline, exine thin and smooth but very sparsely small punctae present which are about one micron in diameter.

SIZE: 39 by 31.2 microns

FIGURED SPECIMEN:

Plate IV, figure 2 Sc 1-24/1 44.7/128.8

Laevigatosporites sp.

Plate IV, figures 5, 6

DESCRIPTION: Monolete, suture straight about 1/2 of the spore length, mostly gaping, outline rounded elliptical to kidney-shaped, exine granulate showing finely reticulate pattern.

SIZE: 31 to 39 by 28 to 31 microns

FIGURED SPECIMEN:

Plate IV, figure 5 Sc 2-C/14 24.6/116.8

figure 6 Sc 1-19/1 48.6/124.6

Monoletes Ibrahim 1933

Monolete sp.

Plate IV, figure 7

DESCRIPTION: Monolete, general outline of equatorial margin plano-convex, exine has blunt spines spread sparsely all over body. Spines about three microns in length, length of the spine at least double the base width. Exine about 1.0 to 1.5 microns thick.

SIZE: 33.8 by 26 microns

FIGURED SPECIMEN:

Plate IV, figure 7 Sc 1-19/1 63.4/120.1

Tetrad of spores

Plate IV, figure 12

DESCRIPTION: Laesurae not clear, exine thin and slightly punctate, indivudual spores are triangularly rounded and are about 26 microns in size.

SIZE OF THE TETRAD: ca. 39 microns

FIGURED SPECIMEN:

Plate IV, figure 12 Sc 2-6/3 58.4/113.0

Genus *Schizosporis* Cookson and Dettmann, 1959

1959 *Schizosporis reticulatus* Cookson and Dettmann, Micropaleont., vol. 5, p. 213, pl. 1, figs. 1-4 (type species).

DIAGNOSIS: Microspores medium to large, with an equatorial line or furrow along which a separation into two approximately equal parts takes place.

Schizosporis cf. *S. parvus* Cookson and Dettmann, 1959

Plate IV, figure 13

1959 *Schizosporis parvus* Cookson and Dettmann, Micropaleont., vol. 5, p. 216, pl. 1, figs. 15-20.

DESCRIPTION: Spore elliptical in both equatorial and polar views, splitting equatorially into two elongate, boat-shaped equal parts, exine smooth, two layered.

SIZE: 49.4 by 33.8 microns

REMARKS: The size range is quite small in the spores recovered; morphology is very similar to *Schizosporis parvus* Cookson and Dettmann.

FIGURED SPECIMEN:

Plate IV, figure 13 Sc 1-24/1 40.6/115.0

Schizosporis cf. S. rugulatus Cookson and Dettmann, 1959

Plate IV, figures 17,18.

1959 Schizosporis rugulatus Cookson and Dettmann, Micropaleont., vol. 5, no. 2, p. 216, pl. 1, figs. 5-9.

DESCRIPTION: Spores almost circular in polar view and biconvex in equatorial view, a little flattened at poles, splitting equatorially into two equal saucer-shaped sections, exine double layered, ectexine ornamented with sinuous ridges uniting in small meshed shallow reticulum, on the reticulum are small spines or granules.

SIZE: length 57.2 to 65 microns

breadth 49.4 to 59.8 microns

REMARKS: The size range is smaller than reported in S. rugulatus by Cookson and Dettmann (1959) and Singh (1964) but comes within the range reported by Pocock (1962).

FIGURED SPECIMEN:

Plate IV,	figure 17	Sc 1-19/2	63.5/122.7
	figure 18	Sc 1-24/1	71.5/119.0

ORDER CYCADALES OR BENNETTITALES

FAMILY CYCADACCAE

Genus Cycadopites Wodehouse, 1933 ex Wilson and Webster, 1946

1933 Cycadopites Wodehouse, Bull. Torrey Botan. Club., vol. 60, p. 483, fig. 56.

1946 Cycadopites follicularis Wilson and Webster, Am. J. Bot., vol. 33, p. 274, pl. 1, fig. 7 (type species designated by Potonie, 1958).

DIAGNOSIS: Monosulcate pollen grains more or less spindle-shaped, sulcus extending the total length of the grain and broadening at the longitudinal ends, sulcus usually closed in the middle by furrow edges overlapping from shrinkage.

Cycadopites sp.

Plate V, figure 2

DESCRIPTION: Monosulcate pollen grain, sulcus broad, furrow edges wide open at one end and reach each other a little before the other end, then again open out. Sulcus extends the whole length of the grain, outline more or less boat-shaped.

SIZE: 54.6 by 26 microns

FIGURED SPECIMEN:

Plate V, figure 2 Sc 1-24/1 18/119.6

Cycadopites sp.

Plate V, figure 3

DESCRIPTION: Monosulcate pollen grain, sulcus narrow, furrow edges meet after middle towards one end, sulcus extends the whole length of the grain and broadens a little at the longitudinal ends, outline elongate fusiform, exine smooth and thin.

SIZE: 72.8 by 18.2 microns

FIGURED SPECIMEN:

Plate V, figure 3 Sc 1-24/1 54.8/124.3

Cycadopites sp.

Plate V, figure 4

DESCRIPTION: Monosulcate pollen grain, sulcus very broad, constricts in the middle, sulcus extends the whole length of the grain and is very broad at the longitudinal ends but not equally broad at both the ends, outline boat-shaped, exine smooth, surface gives infra-reticulate pattern.

SIZE: 104.0 by 52.0 microns

FIGURED SPECIMEN:

Plate V, figure 4 Sc 2-6/3 51/118.6

Cycadopites follicularis Wilson and Webster, 1946

Plate V, figures 5-7

1946 Cycadopites follicularis Wilson and Webster, Am. J. Bot., vol. 33, p. 274, fig. 7.

DESCRIPTION: Monosulcate pollen grain, approximately twice as long as wide, sulcus runs whole length of the grain overlapping in the middle or towards the end and broadens at the longitudinal ends, outline fusiform, exine smooth, shows infra-reticulate pattern in regular lines.

SIZE: 26 to 32 by 15 to 21 microns

FIGURED SPECIMEN:

Plate V, figure 5	Sc 1-24/1	53.8/125.1
figure 6	Sc 1-24/1	44.5/115.3
figure 7	Sc 1-24/1	44/125.5

ORDER CONIFERALES

FAMILY TAXODIACEAE

Genus Taxodiaceaepollenites Kremp, 1949

1931 Pollenites hiatus Potonie, Jb. Preuss Geol. L. A. 1931, vol. 52, p. 5, fig. 27.

1934 Pollenites hiatus Potonie, Arb. Inst. Palaob. Petrogr., Brennsteinne, vol. 4, p. 47, Taf. 1, fig. 30.

1950 Taxodioidites hiatus Potonie in Potonie, Thomson and Thiergart, Geol. Jb., vol. 65, p. 49, Taf. A, fig. 23.

1951 Taxodioipollenites hiatus Potonie, Palaeontographica, vol. 91, Abt. B, Taf. 20, fig. 17.

DIAGNOSIS: Grains rounded, generally split into two halves and remain attached at one end.

Taxodiaceaepollenites (al. Taxodium) hiatipites (Wodehouse, 1933) new combination

Plate V, figures 8, 9

1933 Taxodium hiatipites Wodehouse, Bull. Torr. Bot. Club. vol. 60, p. 493, fig. 17.

1957 Taxodium hiatipites Wodehouse in Rouse, Can. J. Bot., vol. 35, p. 366-367, pl. II, figs. 25, 26.

DESCRIPTION: Pollen rounded, splits into two halves but remains attached at one end, exine thin and punctate.

SIZE: 31.2 by 20.8 to 31.2 microns.

FIGURED SPECIMEN:

Plate V, figure 8	Sc 1-24/1	36/114.9
figure 9	Sc 1-24/1	48.6/116.6

Genus Sequoiapollenites Thiergart, 1937, 1938

1938 Sequoiapollenites polyformosus Thiergart, Jb. Preuss. Geol. L.-A. (1937), vol. 58, p. 301, Taf. 23, fig. 6.

1950 Sequoioidites polyformosus Thiergart in Potonie, Thomson, Thiergart, Geol. Jb., vol. 65, p. 49, Taf. A, figs. 20, 21, Taf. C, fig. 8.

1951 Sequoioipollenites polyformosus Thiergart in Potonie, Palaeontographica, vol. 91, Abt. B, Taf. 20, fig. 16, 16a.

1953 Inaperturopollenites polyformosus Thiergart in Thomson and Pflug, Palaeontographica, vol. 94, Abt. B, p. 165, Taf. 5, fig. 21-25.

DIAGNOSIS: Equatorial contour rounded, exine thick and strong, smooth to slightly infragranular, a papillate protuberance is present.

Sequoiapollenites sp.

Plate V, figure 10

DESCRIPTION: Elliptically rounded pollen grain with a prominent papilla of about 4 to 5 microns. Ornamentation finely granular. Exine thick and strong.

SIZE: 26 microns

FIGURED SPECIMEN:

Plate V, figure 10 Sc 1-19/2 45.5/108.1

FAMILY CUPRESSACEAE

Genus Inaperturopollenites (Pflug, 1952 ex Thomson and Pflug, 1953) emended Potonie, 1958

1933 Laevigata-sporites cf. magnus dubius Potonie in Potonie and Gelletich, S.-b. Ges. nat. Freunde (1932), vol. 33, p. 520, Taf. 2, fig. 11-13.

1934 Pollenites magnus dubius Potonie and Venitz, Arb. Inst. Palaobot. Brennsteinne, vol. 5, p. 17, Taf. 2, fig. 21.

1953 Inaperturopollenites (al. Pollenites magnus dubius) dubius (Potonie and Venitz, 1934) Thomson and Pflug, Palaeontographica, vol. 94, Abt. B, p. 64 (type species).

1953 Inaperturopollenites dubius (Potonie and Venitz, 1934) Thomson and Pflug, Palaeontographica, vol. 94, Abt. B, p. 65, Taf. 4, fig. 89, Taf. 5, figs. 1-13.

DIAGNOSIS: Equatorial contour rounded, exine thin, infrapunctate, secondary folds present. Grains without apertures.

Genus Inaperturopollenites dubius (Potonie and Venitz, 1934) Thomson and Pflug, 1953

Plate V, figures 11-14

Syn. as for Genus.

DESCRIPTION: Inaperturate, equatorial contour rounded, secondary folds in various planes are present, exine thin, infra-punctate, punctate or granulate.

SIZE: 52 to 65 microns

FIGURED SPECIMEN:

Plate V, figure 11 Sc 1-19/3 45.3/129

figure 12 Sc 1-19/1 65.5/129.2

figure 13 Sc 1-19/1 56.9/129.0

figure 14 Sc 1-C_1/3 60.7/126.1

Inaperturopollenites sp.

Plate V, figure 15

DESCRIPTION: Inaperturate, equatorial contour elliptical to rounded, secondary folds present, exine thin, infrapunctate.

SIZE: 104 by 83.2 microns

FIGURED SPECIMEN:

Plate V, figure 15 Sc 2-C_1/1 38.5/124.7

FAMILY PODOCARPACEAE

Genus Podocarpidites Cookson, 1947 ex Couper, 1953

1947 Podocarpidites ellipticus Cookson, B.A.N.Z. Antarctic Res. Expedition, Rept. A2, p. 131, pl. 13, figs. 5-7.

1953 Podocarpidites cf. ellipticus Cookson - Couper, New Zealand Geol. Surv. Paleont. Bull. 22, p. 35.

1957 Pityosporites cf. P. ellipticus (Cookson) Balme, Australia, C.S.I.R.O., Coal Res. Sect., Ref. T.C. 25, p. 35, pls. 9, 10, figs. 104-107.

DIAGNOSIS: Bisaccate pollen grain, equatorial outline of the central body oval to polygonal, marginal crest visible, bladders large and distally pendant and cover the distal surface except for a parallel-sided area corresponding to the distal leptoma, length of the central body always less than length of the bladders. This genus includes bisaccate forms with a very distinct central body, marginal crest, and large, slightly pendant bladders.

Podocarpidites sp.

Plate V, figures 16-19

DESCRIPTION: Bisaccate, equatorial outline of the central body oval to

almost circular, marginal crest distinct, bladders a little longer to equal to the breadth of the body, thin walled with fine reticulation, proximal cap and marginal crest granulose.

SIZE: Total breadth of the grain - 39 to 50 microns

Breadth of the central body - 26 to 29 microns

Length of the central body - 26 to 34 microns

Breadth of bladders - 13 to 29 microns

Length of bladders - 26 to 36 microns

FIGURED SPECIMEN:

Plate V,	figure 16	Sc 1-24/1	68/117.8
	figure 17	Sc 1-24/2	28/118
	figure 18	Sc 2-C_1/1	67.5/121.4
	figure 19	Sc 1-24/3	34.9/115.2

Podocarpidites sp.

Plate VI, figure 1

DESCRIPTION: Bisaccate, equatorial outline of the central body elliptical, marginal crest distinct, bladders longer than the body, bladders are finely reticulate, body granulose.

SIZE: Total breadth of the grain - 67.6 microns

Breadth of the central body - 36.4 microns

Length of central body - 39.0 microns

Breadth of bladders - 31.2 microns

Length of bladders - 46.8 microns

FIGURED SPECIMEN:

Plate VI, figure 1 Sc 1-19/1 48/115.4

Podocarpidites sp.

Plate VI, figure 4

DESCRIPTION: Bisaccate, equatorial outline of the central body elliptical, marginal crest distinct, bladders a little larger than the body, having fine reticulations, marginal crest of the body well developed and is granulose.

SIZE: Total breadth of grain - 78.0 microns

Breadth of central body - 52.0 microns

Length of central body - 57.0 microns

Breadth of bladders - 36.4 microns

Length of bladders - 59.8 microns

FIGURED SPECIMEN:

Plate VI, figure 4 Sc 1-19/1 69.9/129.6

Genus Phyllocladidites Cookson, 1947 ex Couper, 1953

1947 Disaccites (Phyllocladidites) mawsonii Cookson, B.A.N.Z. Antarctic Res. Expedition, Rept. A2, p. 133, pl. 14, figs. 22-28.

1953 Dacrydiumites mawsonii (Cookson) Cookson, Australian J. Botany, vol. 1, p. 66, Bull. 22, p. 38, pl. 9, fig. 135 (type species).

1953 Dacrydiumites mawsonii (Cookson) Cookson, Australian J. Bot., vol. 1, p. 66, pl. 1, figs. 9-26.

1957 Dacrydium mawsonii (Cookson) Cookson, Proc. Roy. Soc. Victoria, vol. 69, p. 53.

1960 Dacrydium mawsonii Cookson - Couper, New Zealand Geol. Surv. Paleont. Bull. 32, p. 43, pl. 3, figs. 7, 8.

DIAGNOSIS: Bisaccate, equatorial outline of the body circular, oval or polygonal, proximal cap distinct and extending into the distal surface, bladders very small with indistinct reticulum, strongly pendant distally, bladders not extending far beyond equator of the central body, a broad clearly defined distal furrow present between the two bladders, bladders commonly thick and rigid, exine firm, finely

granular, and conspicuously thickened at the proximal root of each bladder close to the equatorial margin.

Phyllocladidites sp.

Plate VI, figure 3

DESCRIPTION: Bisaccate, equatorial outline of the body almost circular to oval, bladders elongate, kidney-shaped, smaller than the body, bladders thick with irregular reticulations and are attached the full length of the body, sulcus between the two bladders present, margin of the body thick and strong.

SIZE: Breadth of central body 49.4 microns

Length of central body 52.0 microns

Breadth of bladders 33.8 microns

Length of bladders 44 microns.

FIGURED SPECIMEN:

Plate VI, figure 3 Sc 2-C/15 53.4/112.5

Phyllocladidites sp.

Plate VI, figure 6

DESCRIPTION: Bisaccate, equatorial outline of the body circular, bladders elongate, narrow, and curved towards the body, almost equal to the length of the body, attached along their whole length to the body, bladders thick, notched and with firm irregular reticulum.

SIZE: Breadth of central body 67.6 microns

Length of central body 65.0 microns

Breadth of bladders 26 microns

Length of bladders 62.4 microns

FIGURED SPECIMEN:

Plate VI, figure 6 Sc 1-24/2 35.9/128.0

FAMILY PINACEAE

Genus Cedripites Wodehouse, 1933

1933 Cedripites eocenicus Wodehouse, Bull. Torry Botan. Club, vol. 60, p. 489-490, fig. 13 (type species).

DIAGNOSIS: Bisaccate pollen with thick proximal cap and somewhat curved marginal crest, bladders fused with proximal cap giving the impression of continuity along the proximal pole, bladders concave on the distal side, partially covering the central body in that region.

Cedripites sp.

Plate VI, figures 5,7-10

DESCRIPTION: Bisaccate, central body oval to somewhat circular in equatorial outline, proximal cap thick, bladders concave on distal side, partially covering the central body in that region, exine of the bladders fused with the exine of the proximal cap, bladders have reticulate ornamentation, proximal cap granulose.

SIZE: Total breadth of grain 83 to 110 microns

Breadth of central body 46 to 78 microns

Length of central body 52 to 78 microns

Breadth of bladders 39 to 52 microns

Length of bladders 52 to 68 microns

FIGURED SPECIMEN:

Plate VI, figure 5	Sc 1-19/3	70/114.3
figure 7	Sc 1-19/3	27.5/118.7
figure 8	Sc 1-19/1	66.2/129.3
figure 9	Sc 1-19/2	43.2/128.5
figure 10	Sc 1-19/2	48.9/128.2

ORDER CONIFERALES - INCERTAE SEDIS

Genus Pityosporites Seward, 1914, emended Manum, 1960

1914 Pityosporites antarcticus Seward, British Antarctic (Terra Nova) Expedition 1910, Nat. Hist. Rept., Geol. 1, p. 23, pl. 8, fig. 45 (type species).

1954 Pityosporites Seward emended Potonie and Klause, Geol. Jahrb., vol. 68 p. 534.

1958 Pinuspollenites Raatz ex Potonie, Beih. Geol. Jahrb, Heft 31, p. 62, pl. 8, figs. 75, 76.

1960 Pityosporites antarcticus Seward emended Manum, Nytt. Mag. Bot., vol. 8, p. 14, pl. 1, figs. 1-4.

DIAGNOSIS: Bisaccate pollen grains, bladders distally pendant, narrowing towards their roots and diverging, proximally the roots reach the equator of the body or slightly beyond it, distally the roots are separated by a more or less narrow furrow, bladders reticulate, body wall smooth or very finely sculptured, exine thickness moderate and not conspicuously increasing towards the roots of the bladders.

Pityosporites sp.

Plate VI, figure 2

DESCRIPTION: Bisaccate, bladders narrow towards their roots and diverging, roots reaching slightly beyond the equator, central body oval, broader than long, bladders finely reticulate, body finely reticulate and exine uniformly thick.

SIZE: Total breadth of grain - 78.0 microns

Breadth of central body - 59.8 microns

Height of central body - 46.8 microns

Breadth of bladders - 36.4 microns

Height of bladders - 39.0 microns

FIGURED SPECIMEN:

Plate VI, figure 2 Sc 1-18/1 34.7/119.2

POLLENITES INCERTAE SEDIS

Genus Monosulcites (Cookson) ex Couper, 1953

1947 Monosulcites minimus Cookson, B.A.N.Z. Antarct. Res. Exped. (1929-1931) Rept. A2 (acd), pt. 8, p. 135, pl. 15, figs. 47-50 (type species; subsequent designation).

1953 Monosulcites minimus (Cookson) ex Couper, New Zealand Geol. Surv. Paleont. Bull. 22, p. 65.

DIAGNOSIS: Microspores, outline boat-shaped to more or less circular, exine smooth, infrapunctate or infragranular, germinal area long, almost equal to the length of the grain. The greatest width of the furrow is usually in the center.

Monosulcites sp.

Plate IV, figure 14

DESCRIPTION: Pollen elliptical in equatorial view, sulcus long, running the length of the body, broader at one pole, exine slightly irregularly reticulate, exine thin and double-layered.

SIZE: 65 by 31.2 microns

FIGURED SPECIMEN:

Plate IV, figure 14 Sc 1-24/1 21.5/114.0

Monosulcites sp.

Plate IV, figures 15, 16

DESCRIPTION: Pollen small, oval to elliptical, sulcus runs the length of the pollen, sulcus opening almost of equal width throughout the length, exine punctate.

SIZE: 31.2 by 20.8 microns

FIGURED SPECIMEN:

Plate IV, figure 15 Sc 1-24/1 40.5/108.3

figure 16 same as figure 15 but under higher magnification.

Monosulcites sp.

Plate IV, figure 19

DESCRIPTION: Pollen elliptical, sulcus runs all along the body and closed, lips overlap in the center of the body, exine strongly scabrate and double layered.

SIZE: 52.0 by 28.6 microns

FIGURED SPECIMEN:

Plate IV, figure 19 Sc 1-24/1 65.7/120.8

Monosulcites sp.

Plate V, figure 1

DESCRIPTION: Pollen splits at the equatorial plane along the sulcus into two parts, little contorted, sulcus margins thickened widely.

It compares with Glyptostrobus vacuipites Wodehouse (1933) but differs in its exine being smooth.

SIZE: 78 by 39 microns

FIGURED SPECIMEN:

Plate V, figure 1 Sc 1-24/1 25.2/123.9

ANGIOSPERMAE

FAMILY URTICACEAE

Genus Momipites Wodehouse, 1933

1933 Momipites coryloides Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 511, fig. 43 (type species).

DIAGNOSIS: Grains spheroidal or oblately flattened and somewhat triangular in outline. Pores three on the equator with their apertures broadly elliptical and meridionally oriented, only slightly protruding above the surface and with exine immediately surrounding them slightly thickened, corresponding to the Corylus pattern. Texture smooth.

Momipites coryloides Wodehouse, 1933

Plate VII, figures 1, 2

1933 Momipites coryloides Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 511, fig. 43.

1946 Momipites coryloides Wodehouse - Wilson and Webster, Am. J. Bot., vol. 33, p. 275-276, fig. 15.

DESCRIPTION: Triporate, triangularly spherical in equatorial outline, pores three on equator of the grain slightly protruding above the surface, exine immediately surrounding the pores is slightly thickened.

SIZE: 23 to 32 microns

FIGURED SPECIMEN:

Plate VII,	figure 1	Sc 1-24/1	50.7/122.4
	figure 2	Sc 2-C_1/3	24.5/128.4

FAMILY BETULACEAE

Genus Alnipollenites Potonie, 1931

1931 Alnus sp. Kirchheimer, N. Jb. Miner. etc. Beil., vol. 67, Abt. B, p. 307, Taf. 13, fig. 1.

1933 Alnus speciipites Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 508, fig. 40.

1950 Alnus-pollenites metaplasmus Potonie - Potonie, Thomson and Thiergart, Geol. Jb., vol. 65, p. 53, Taf. B, fig. 18, Taf. C, fig. 20.

1953 Polyvestibulopollenites verus Potonie - Thomson and Pflug, Palaeontographica, vol. 94, Abt. B, p. 90, Taf. 10, fig. 73.

DIAGNOSIS: Pores 4 to 7, seldom three, situated in equatorial plane, when pores four or more polar view is square or polygonal. Exine smooth or slightly roughened, greatly thickened in the region surrounding pores so that pore protrudes markedly and grain has an angular appearance. Exine is also thickened forming arci.

Alnipollenites quadrapollenites (Rouse, 1962) new combination

Plate VII, figure 3

1962 Alnus quadrapollenites Rouse, Micropaleontology, vol. 8, no. 2, p. 202, pl. 2, figs. 9, 36.

DESCRIPTION: Tetraporate pollen grains, square in equatorial contour. Four pores situated at the angles. Bands of the exinous wall connecting the pores are conspicuous. Exine around the pores slightly thick. Exine laevigate, ornamentation infra-punctate.

SIZE: Equatorial diameter 18.2 microns

FIGURED SPECIMEN:

Plate VII, figure 3 Sc 2-C/13 24.3/126.1

FAMILY MYRICACEAE

Genus Myricipites Wodehouse, 1933

1933 Myricipites dubius Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 506, fig. 33.

DIAGNOSIS: Pores three, approximately spheroidal, greatly protruding, texture smooth.

Myricipites dubius Wodehouse, 1933

Plate VII, figures 4-6

Syn. as for genus.

DESCRIPTION: Triporate, triangularly spheroidal equatorial outline, pores protruding, exine smooth, ornamentation infrapunctate.

SIZE: 20 to 26 microns

FIGURED SPECIMEN:

Plate VII, figure 4	Sc 1-24/2	70/112.5
figure 5	Sc 1-24/2	56.6/122.8
figure 6	Sc 1-24/1	69.7/114.6

FAMILY PROTEACEAE

Genus Proteacidites Cookson ex Couper, 1953

1950 Proteacidites adenanthoides Cookson, Australian J. Sci. Res., Series B - Biol. Sci., vol. 3, no. 2, p. 172, pl. 2, fig. 21 (type species).

1953 Proteacidites adenanthoides Cookson - Couper, New Zealand Geol. Surv. Paleont. Bull. 22, p. 42.

DIAGNOSIS: Free, isopolar or subisopolar, triorate, occasionally diorate. Grain triangular to subtriangular, sides concave to convex between ora in polar view. Exine clearly differentiated into nexine and sexinous layers. Sexine baculate, clavate or tuberculate, forming a very variable pitted-reticulate, or pseudo-reticulate sculpture in surface view.

Proteacidites sp.

Plate VII, figure 7

DESCRIPTION: Grain triangular in outline, sides between the ora a little convex in polar view. Exine thick two layered, nexine continuous in ora zone. Ora region concave. Ornamentation granulate.

SIZE: 54.6 microns

FIGURED SPECIMEN:

Plate VII, figure 7 Sc 1-24/1 51/112

FAMILY RHIZOPHORACEAE

Pollen cf. family Rhizophoraceae

Plate VII, figures 8-11

DESCRIPTION: Tricolporate, apertures are equatorially situated, pollen triangular in equatorial contour, sides between the pores slightly convex, nexine continuous to form the pore chamber, short colpi generally restricted to the pore

chambers but sometimes they cross a little, exine thick, double layered, granulate, ornamentation reticulate.

SIZE: 23 to 29 microns

FIGURED SPECIMEN:

Plate VII, figure 8	Sc 1-24/1	33.9/124.6
figure 9	Sc 1-24/3	70.6/120.0
figure 10	Sc 1-24/1	26.8/114.5
figure 11	Sc 1-24/2	44.8/113.5

FAMILY ANACARDIACEAE

Genus Rhoipites Wodehouse, 1933

1931 Pollenites pseudocingulum Potonie, Z. Braunkohle, vol. 30, Taf. 1, fig. 3.

1931 Pollenites dolium Potonie, S-B Ges. nat. Freunde, Jahrg. 1931, Nr. 1-3, Taf. 1.

1933 Rhoipites bradleyi Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 513, fig. 45 (type species).

1934 Pollenites pseudocingulum Potonie, Arb. Inst. Palaob. Petrogr. Brennsteine, vol. 4, p. 74, Taf. 3, figs. 28, 29.

DESCRIPTION: Ellipsoidal, tricolpate with furrows long and pointed. Furrow and pore thickenings conspicuous, projecting deeply inwards. Exine rather finely reticulate-pitted.

Rhoipites bradleyi Wodehouse, 1933

Plate VII, figure 12

Syn. as for genus.

DESCRIPTION: Tricolpate grains, ellipsoidal in equatorial view, furrows long and pointed. Furrow and pore thickenings conspicuous, projecting deeply inwards. Exine finely reticulate-pitted.

SIZE: 33.8 by 33.8 microns

FIGURED SPECIMEN:

Plate VII, figure 12 Sc 1-24/3 66.3/129.3

FAMILY SALICACEAE

Pollen cf. Salix sp.

Plate VII, figures 13, 15

DESCRIPTION: Tricolpate, three lobed, isodiamtric, slightly elongate or oblately flattened according to the degree of expansion, furrows long and tapering, without internal marginal thickenings and without germ pores. Exine thick and coarsely reticulate with the reticulum generally finer towards the margins of the furrows and towards the poles.

SIZE: 28 to 30 microns

FIGURED SPECIMEN:

Plate VII, figure 13 Sc 1-24/1 36/125.4

figure 15 Sc 2-C_1/1 31/127.7

FAMILY AQUIFOLIACEAE

Pollen cf. Ilex sp.

Plate VII, figure 14

DESCRIPTION: Tricolpate (may be colporoidate), spheroidal prolate, sexine consists of conspicuous piloid rodlets, colpi long, due to heavy ornamentation furrow morphology not well seen.

SIZE: 36.4 by 26 microns

FIGURED SPECIMEN:

Plate VII, figure 14 Sc 1-24/1 47/109.6

FAMILY OLEACEAE

Genus Fraxinoipollenites Potonie, 1951

1934 Pollenites confinis pudicus Potonie, Arb. Inst. Palaob. Petrogr. Brennsteinne, vol. 4, p. 90, Taf. 5, figs. 12, 15.

1951 Fraxinoipollenites pudicus (Potonie, 1934), Potonie, Mikroskopie, vol. 6, p. 277, Taf. 1, fig. 49.

1951 Fraxinoipollenites pudicus (Potonie, 1934) Potonie, Palaeontographica, vol. 91, Abt. B, Taf. 21, fig. 174, 175.

1962 Fraxinus linguapollenites Rouse, Micropaleontology, vol. 8, no. 2, p. 206-207, pl. 4, figs. 22, 23.

DIAGNOSIS: Shape long ovoid to fusiform, three long colpi without pores, exine granulate to reticulate, furrows like notch.

Fraxinoipollenites sp.

Plate VII, figure 16

DESCRIPTION: Shape ovoid to fusiform, colpi long like notches, pore not seen, exine thick, ornamentation reticulate.

SIZE: Equatorial diameter ca. 26 to 28.6 microns

Polar axis ca. 31.2 microns

FIGURED SPECIMEN:

Plate VII, figure 16 Sc 2-C_1/1 20.6/128.0

FAMILY MYRTACEAE

Genus Myrtaceidites (Cookson and Pike, 1954) emended Potonie, 1960

1954 Myrtaceidites mesonesus Cookson and Pike, Australian J. Bot., vol. 2, no. 2, p. 205, pl. 1, figs. 32-36 (type species).

1960 Myrtaceidites mesonesus Cookson and Pike - Potonie, Beih. Geol. Jb., vol. 39, p. 120, Taf. 7, fig. 154.

DIAGNOSIS: Grains small to medium, 15 to 30 microns in equatorial diameter, amb with convex, straight or concave sides, oblate to subspheroidal, arci prominent, enclosing or not enclosing polar islands, exine ca. 1 micron, thicker around the apertures, obscurely patterned, rarely psilate.

Myrtaceidites sp.

Plate VII, figure 20

DESCRIPTION: Pollen small, amb straight to slightly convex, triangular in polar view, syncolpate condition, no polar island.

SIZE: Equatorial diameter 18.2 microns

FIGURED SPECIMEN:

Plate VII, figure 20 Sc 2-5/1 63.5/119.2

Myrtaceidites sp.

Plate VII, figure 21

DESCRIPTION: Pollen very small, sides straight to little concave, colpi reaching only half way, arci not pronounced, obscurely patterned.

SIZE: Equatorial diameter 15.6 microns

FIGURED SPECIMEN:

Plate VII, figure 21 Sc 2-C_1/2 32.3/120.3

FAMILY FAGACEAE

Genus Quercoidites Potonie, Thomson and Thiergart, 1950

1931 Pollenites microhenriei Potonie, 2. Mitt., p. 26, Taf. 1, fig. V 190.

1934 Pollenites henriei Potonie, Potonie and Venitz, Arb. Inst. Palaobot. Petrogr. Brennsteine, vol. 5, Taf. 2, fig. 61.

1950 Quercoidites henriei (Potonie) Potonie in Potonie, Thomson and Thiergart, Geol. Jb., vol. 65, p. 54-55, Taf. B, fig. 22, 25.

1951 Pollenites microhenriei Potonie, Palaeontographica, vol. 91, Abt. B, Taf. 20, fig. 64.

1955 Quercus williamsoniarus Traverse, U. St. Dept. Int. Bur. Mines, Rept. Invest., 5151, p. 48, fig. 45.

DIAGNOSIS: Equatorial view spindle shaped, conical towards the poles, colpi long reaching poles, exine infra-baculate.

Quercoidites sp.

Plate VII, figures 22, 23

DESCRIPTION: Tricolpate, spherical in polar view and spindle shaped equatorial view, colpi long reaching the poles, exine infra-baculate giving faint reticulate pattern in surface view.

SIZE: 26 by 18.2 microns in equatorial view.

FIGURED SPECIMEN:

Plate VII, figure 22	Sc 2-C_1/1	23.7/125.5
figure 23	Sc 2-C/1	68.6/115.9

FAMILY JUGLANDACEAE

Genus Juglanspollenites Raatz, 1937

1937 Juglanspollenites verus Raatz, Abb. preuss. geol. L.-A.N.F., vol. 183, p. 18, Taf. 1, fig. 9.

DIAGNOSIS: Equatorial contour polygonal, 6 to 10 pores on the equatorial plane situated on the angular protrusions, exine pattern faint.

Juglanspollenites sp.

Plate VIII, figure 1

DESCRIPTION: Seven-porate pollen grain, polygonal in equatorial contour and angular at the pores, sides slightly concave, folds parallel to the sides are seen, exine infra-reticulate.

SIZE: 44 microns

FIGURED SPECIMEN:

Plate VIII, figure 1 Sc 2-C/15 35.5/114.0

FAMILY ERICACEAE

Genus Ericipites Wodehouse, 1933

1933 Ericipites longisulcatus Wodehouse, Bull. Torr. Bot. Club, vol. 60, p. 517, fig. 52 (type species).

DIAGNOSIS: Pollen grains in tetrahedral tetrads, generally tightly appressed. Exine rather thin, smooth or somewhat granular. Furrows of each grain of the tetrad three, of various lengths in different species, each contiguous and continuous with one of the furrows of each of its three neighbours across the suture between their contact faces. Pores three, enclosed by the furrows, those of adjacent furrows close to and facing each other across the suture.

Ericipites sp.

Plate VIII, figures 2-4

DESCRIPTION: Tetrahedral tetrads tightly appressed, exine thin, slightly granular.

SIZE: 33 to 42 microns. Single grains 20 to 30 microns

FIGURED SPECIMEN:

Plate VIII,	figure 2	Sc 2-6/3	29.6/128.3
	figure 3	Sc 2-C/14	44.5/125.2
	figure 4	Sc 2-C/14	24.1/116.8

FAMILY MAGNOLIACEAE

Pollen cf. Liriodendron psilopites Wodehouse, 1933

Plate VIII, figure 5

DESCRIPTION: Monosulcate, pollen grain long, sulcus long with uniform opening throughout the length, exine smooth but radial ridge-like patterns run from the sulcus towards the margin.

SIZE: 49.9 by 15.6 microns

FIGURED SPECIMEN:

Plate VIII, figure 5 Sc 2-C/15 56.4/111.3

FAMILY LILIACEAE

Genus Liliacidites Couper, 1953

1953 Liliacidites kaitangataensis Couper, New Zealand Geol. Surv. Paleont. Bull. 22, p. 56, pl. 7, fig. 97 (type species).

DIAGNOSIS: Free, anisopolar, bilateral, monosulcate, occasionally trichotomosulcate, sulcus long, broad, pollen usually elongate. Exine clearly reticulate, lumen of reticulation variable in size, clavate, baculate in optical section.

Liliacidites sp.

Plate VIII, figure 6

DESCRIPTION: Monosulcate, sulcus widely open at one pole and meets at the other, exine thin, having little blunt rodlets all over the body, sparsely scattered.

SIZE: 46.8 by 28.6 microns

FIGURED SPECIMEN:

Plate VIII, figure 6 Sc 2-C/13 21.7/123.2

Liliacidites sp.

Plate VIII, figures 7-9

DESCRIPTION: Monosulcate, sulcus runs throughout the length of the body, sometimes folds are also present, exine has reticulate ornamentation.

SIZE: 44 to 50 by 26 microns

FIGURED SPECIMEN:

Plate VIII,	figure 7	Sc 1-24/2	30.2/122.8
	figure 8	Sc 2-B/1	38.8/108.0
	figure 9	Sc 1-24/1	45.4/127.5

FAMILY LORANTHACEAE

cf. Elytranthe sp.

Plate XI, figures 1-7

DESCRIPTION: Free isopolar, tricolporate, colpi short, narrow, shape peroblate, sub-triangular, apices broadly truncated, sides concave between in polar view, exine finely scabrate, granules arranged into striations.

SIZE: Polar view 28 to 32 microns

REMARKS: Such pollen have been assigned by Couper (1953) to the modern

genus Elytranthe, however, these show a gradational relationship to some forms belonging to the genus Aquilapollenites also. In a few pollen grains there is a round dense small polar area.

FIGURED SPECIMEN:

Plate XI,	figure 1	Sc 1-24/1	49.4/128.7
	figure 2	Sc 1-24/3	67/130
	figure 3	Sc 1-24/1	59.4/112.2
	figure 4	same as figure 1	
	figure 5	Sc 1-24/1	18.2/128.3
	figure 6	same as figure 2	
	figure 7	same as figure 3	

cf. Elytranthe sp.

Plate XI, figure 9

DESCRIPTION: Free, isopolar, tricolpate or tricolporoidate, colpi reaching more than half the length towards the pole in polar view, shape almost square, apices bluntly angular, sides straight between colpi in polar view, exine finely scabrate, granules arranged into striations.

SIZE: 36.4 microns in polar view.

FIGURED SPECIMEN:

Plate XI, figure 9 Sc 1-24/1 48/125.2

REMARKS: This type of pollen has broad morphological characters like those of Elytranthe but differs in having four colpi which probably have not been reported under this genus.

FAMILY RESTIONACEAE

Pollen cf. family Restionaceae

Plate XI, figure 14

DESCRIPTION: Free, isopplar, monoporate, exine scabrate, ornamentation reticulate.

SIZE: 57.2 microns

REMARKS: Similar pollen grain have been reported by Couper (1953) as belonging to family Restionaceae.

FIGURED SPECIMEN:

Plate XI, figure 14 Sc 1-19/1 69/115.5

ANGIOSPERMAE - INCERTAE SEDIS

Genus Tricolpites Cookson, 1947 ex Couper, 1953

1947 Tricolpites reticulatus Cookson, B.A.N.Z. Antarctic Res. Expedition 1929-1931, Repts- Series A, vol. 2, p. 134, pl. 15, fig. 45.

1953 Tricolpites reticulatus Cookson, in Couper, New Zealand Geol. Surv. Paleont. Bull. 22, p. 61.

DIAGNOSIS: Free, isopolar, tricolpate. Exine variable in thickness and sculpture. Size variable.

Tricolpites sp.

Plate VII, figures 17-19

DESCRIPTION: Free, isopolar, tricolpate, equatorial contour in polar view rounded, colpi long and situated at the angles, amb convex, infra-reticulate ornamentation.

SIZE: Equatorial diameter 20 to 29 microns

REMARKS: Similar grains have been referred by Rouse (1957) to genus Sapindus.

FIGURED SPECIMEN:

Plate VII,	figure 17	Sc 1-24/2	39.7/128.4
	figure 18	Sc 1-19/2	72.4/118.1
	figure 19	Sc 1-24/2	56.4/123.0

Tricolpites sp.

Plate VII, figures 24, 25

DESCRIPTION: Free, isopolar, tricolpate, equatorial contour triangularly rounded, colpi between the angles or it may be said that amb is very much convex so as to give such an impression. Colpi long reaching the polar area. Exine thin infragranulate.

SIZE: Equatorial diameter 26 microns

FIGURED SPECIMEN:

Plate VII,	figure 24	Sc 2-C/15	25.3/111.6
	figure 25	Sc 2-C_1/1	27.5/118.1

Tricolpites sp.

Plate VII, figure 26

DESCRIPTION: Free, isopolar, tricolpate, equatorial contour rounded, colpi long wide open, amb convex, exine finely reticulate.

SIZE: Equatorial diameter 31.2 microns

REMARKS: Such pollen grains have been described and identified by Samoilovich and Mtchedlishvili (1961) under genus Platanus from Maestrichtian of Russia.

FIGURED SPECIMEN:

Plate VII, figure 26 Sc-C/13 65.9/122.3

Genus Tetracolpites new genus

DIAGNOSIS: Free, isopolar, tetracolpate, colpi long, exine psilate to sculptured.

TYPE SPECIES: Tetracolpites reticulatus new species, pl. VII, fig. 27

REMARKS: Vimal (1952) mentioned a few pollen grains having four colpi as tetracolpites but neither designated it to generic level nor established the type species. The purpose of forming this genus is to accommodate the tetracolpate pollen similar to Polycolpites Couper, 1953 emended, and cannot be assigned to any known genus.

Tetracolpites reticulatus new species

Plate VII, figure 27

DESCRIPTION: Tetracolpate, squarely rounded, colpi broad and long, exine has fine reticulations.

SIZE: Equatorial diameter 39 microns

FIGURED SPECIMEN (Holotype):

Plate VII, figure 27 Sc 2-C/14 67.6/121.1

Genus Polycolpites Couper, 1953 emended

1953 Polycolpites clavatus couper, New Zealand Geol. Surv. Paleont. Bull. 22, p. 63, pl. 8, figs. 123, 124 (type species).

DIAGNOSIS: Free, isopolar, polycolpate, colpi five or more than five, long, exine psilate to sculptured.

REMARKS: Couper (1953) in designating genus Polycolpites has given number of colpi as "more than six in number," but in describing Polycolpites reticulatus Couper, 1960, has noted colpi numbers five to six without emending the generic description. To accommodate all such pollen grains having colpi numbers five or more than five and which

cannot be assigned to any particular genus, genus Polycolpites has been emended.

Polycolpites sp.

Plate VII, figures 28 - 30

DESCRIPTION: Colpi 5 to 6, grains circular in polar view, exine about one micron thick, finely reticulate, colpi broad and long.

SIZE: Equatorial diameter 52 microns

FIGURED SPECIMEN:

Plate VII, figure 28	Sc 2-C/13	62/125.9
figure 29	Sc 2-C/13	43/128.4
figure 30	Sc 2-C_1/1	49.8/127.6

Polycolpites sp.

Plate VII, figure 31

DESCRIPTION: Hexacolpate, colpi long, exine thin, finely reticulate.

SIZE: In equatorial view 41.6 by 33.8 microns

FIGURED SPECIMEN:

Plate VII, figure 31 Sc 1-24/1 38/124.0

Genus Aquilapollenites (Rouse, 1957) emended Funkhouser, 1961

1957 Aquilapollenites quadrilobus Rouse, Can. J. Bot., vol. 35, p. 371, pl. II, figs. 8, 9. (type species)

DIAGNOSIS: Angiosperm pollen, heteropolar or isopolar, one or both of the poles extended into polar protrusions, three, often winglike, equatorial protrusions. Apertures of several types, often difficult to see in normal orientation, usually three

colpi or three pairs of demicolpi on the outer margins of the equatorial protrusions. In addition, there may be three colpi on and parallel to the equator between the equatorial protrusions. Grains may be more or less smooth or sculptured (punctae, reticulae, spines, striae, etc.)

Aquilapollenites subtilis Mtchedlishvili, 1961

Plate VIII, figures 10-12

1961 Aquilapollenites subtilis Mtchedlishvili, Trud. VNIGRI, vol. 167, p. 214, pl. 68, figs. 2-4.

1961 Aquilapollenites amplus Stanley, Pollen et Spores, vol. 3, no. 2, p. 342-346, pl. 1, figs. 1-6, pl. 2, figs. 1-4, pl. 3, figs. 1-5.

DESCRIPTION: Isopolar, tricolpoidate aquila grain, exine about two microns thick, ornamentation fine reticulate, spines with broad base and pointed tips. Spines average four microns in length. Endexine thins out towards distal ends of the protrusions. Spines are more in number at the distal portion of the protrusions, mostly with their tips directed towards the body. Endexine thickens towards the body from the protrusions and thins out shortly into the body. Colpoids not very distinct.

SIZE: Diameter of the body 30 microns

Length of the polar axis 60 microns

Length of the body protrusions 26 microns

FIGURED SPECIMEN:

Plate VIII,	figure 10	Sc 2-6/2	44/115
	figure 11	same as figure 10	
	figure 12	same as figure 10	

Aquilapollenites spinulosus Funkhouser, 1961

Plate VIII, figures 16, 17

1961 Aquilapollenites spinulosus Funkhouser, Micropaleontology, vol. 7, no. 2, p. 194, pl. 1, figs. 4-6.

DESCRIPTION: Isopolar, poles extended into protrusions, three equatorial protrusions, areas between the tips of the equatorial protrusions and the poles concave, along these concavities are borne the three pairs of demicolpi. Diameter of polar protrusions about 1/3 polar axis, from the polar axis to the tip of an equatorial protrusion is about 1/2 the polar axis, diameter of equatorial protrusions about 1/3 polar axis. Except for narrow bands parallelling the demicolpi, entire surface covered by randomly spaced spinules, spaced one to two times their basal diameter. Spines about 2.5 microns long with broad base. Wall stratification obscure.

SIZE: Polar axis 36 microns

From tips of equatorial protrusions to polar axis about 18 to 26 microns.

REMARKS: One of the equatorial protrusions seems flattened in few of the grains. It is not clear if it is folded or if it is characteristic.

FIGURED SPECIMEN:

Plate VIII, figure 16	Sc 1-24/1	41.5/115.2
figure 17	same as figure 16	

Aquilapollenites pulcher Funkhouser, 1961

Plate VIII, figures 13-15, 20

1961 Aquilapollenites pulcher Funkhouser, Micropaleontology, vol. 7, no. 2, p. 198, pl. 1, figs. 7a-c.

DESCRIPTION: Heteropolar, one pole more or less rectangular in plane view and protruded above equatorial protrusions. The other pole shows only a slight convexity below the equatorial protrusions. Protruded pole ca. 1/2 as wide as polar axis, equatorial protrusions slant backward slightly from it, making more or less 20°

angle with the polar axis. From tip of an equatorial wing to polar axis is 4/5 polar axis.

Tridemicolpate, demicolpi relatively short and confined to areas of local wall thickening. These start where the equatorial protrusions meet the main body of the grain and extend along their polar surfaces for a little less than half the distance to their tips. The areas of wall thickening involved here appear to be completely unornamented laterally.

Most of the grain covered with spinules, those of the polar areas are larger and more widely spaced than those of the equatorial protrusions. The former tend to project more or less poleward until the tips of the poles are reached, where they are more or less perpendicular to the surface, those of the equatorial protrusions project backwards toward the polar axis. The area of the short polar protrusion is more or less covered by punctae in addition to spinules. A band of punctae surrounds the long polar protrusion from where the equatorial protrusions meet it to a point about halfway to its tip. Exine thickness about two microns and double layered.

SIZE: Polar axis 39 microns

Tip of equatorial protrusions to polar axis 21 microns.

FIGURED SPECIMEN:

Plate VIII,	figure 13	Sc 1-24/1	34.8/121.3
	figure 14	Sc 1-24/1	59.5/124
	figure 15	Sc 1-24/1	22.3/119.6
	figure 20	same as figure 15	

<u>Aquilapollenites</u> sp.

Plate VIII, figures 18, 19

DESCRIPTION: Aquila pollen grain, polar protrusions short, equatorial protrusions quite big and bluntly apical, sides joining the equatorial protrusions much

concave, pollen grains mostly seen in polar view, equatorial contour triangular with polar protrusion in the center. Colpi equatorially placed and extend towards poles on either sides from the apices of the equatorial protrusions and reach the polar protrusion. Exine thicker towards the center of the concave sides of equatorial protrusions, exine surface punctate, sometimes punctae arranged in striate fashion.

SIZE: From the tip of the equatorial protrusion to the polar axis ca. 28.6 microns.

Equatorial diameter 46.8 microns

Diameter of the polar protrusion about 16 microns.

FIGURED SPECIMEN:

Plate VIII,	figure 18	Sc 6/2	55.8/109.3
	figure 19	Sc 1-24/1	44.8/122.4

<u>Aquilapollenites</u> sp.

Plate IX, figures 1,2

DESCRIPTION: Aquilia pollen grain, conspicuous polar and equatorial protrusions, at the protrusions sometimes blunt spines are present which are sparsely scattered. Exine finely reticulate. Colpi not very conspicuous, equatorial protrusions generally distorted.

SIZE: Length of equatorial protrusion up to polar axis 28.6 microns

Equatorial diameter ca. 49.4 to 59.8 microns

Diameter of polar protrusion about 20.8 to 26 microns.

FIGURED SPECIMEN:

Plate IX,	figure 1	Sc 2-6/2	35.5/117.1
	figure 2	Sc 1-24/1	50.7/125.2

Aquilapollenites sp.

Plate IX, figures 3, 4

DESCRIPTION: Aquilia-like grains, polar protrusions not well pronounced, equatorial protrusions are well extended and end into sharp apices, colpi extend from these apices from one equatorial protrusion to the other or may end shortly, exine quite thick and strong, punctate striate.

SIZE: Equatorial diameter 39 to 41.6 microns

FIGURED SPECIMEN:

Plate IX,	figure 3	Sc 1-24/1	40.7/116.9
	figure 4	Sc 1-24/1	24.6/127.9

Aquilapollenites sp.

Plate IX, figures 5-8, 10

DESCRIPTION: Aquila pollen, almost isopolar, one pole round with flattened top while the other mostly conical slightly, equatorial protrusions small rounded peg-like structures with fine reticulate pattern of the exine. Three pairs of demicolpi run from the sides of equatorial protrusions, body of the grain reticulate with lumina of about 2 to 4 microns, large with thick muri, exine thick.

SIZE: Body 33.8 to 48.6 by 18 to 29 microns

Equatorial protrusions ca. 10 to 12 microns

FIGURED SPECIMEN:

Plate IX,	figure 5	Sc 1-24/1	28.2/128.3
	figure 6	same as figure 5	
	figure 7	same as figure 5	
	figure 8	Sc 1-24/1	33/128.7
	figure 10	same as figure 8	

Aquilapollenites sp.

Plate IX, figures 11-13

DESCRIPTION: Aquila pollen, isopolar, polar protrusions well extended, poles rounded with flattened top, exine clavate and body of poles is conspicuously striated by wavy bands. Between the equatorial protrusions and polar extension a few striations are parallel to equatorial axis and then parallel to polar axis. Equatorial protrusions are well-extended peg-like structures with rounded ends, striations of equatorial protrusions are parallel to the polar axis, colpi run through the equatorial protrusions. Exine thins out to the equatorial protrusions.

SIZE: Polar axis 62.4 to 83.2 microns

Polar width 20.8 to 26.0 microns

Equatorial protrusions 36.4 microns

Width of the equatorial protrusions 13 microns

FIGURED SPECIMEN:

Plate IX,	figure 11	Sc 2-C/14	44.2/125.3
	figure 12	same as figure 11	
	figure 13	Sc 2-C_1/1	70.6/115.3

Aquilapollenites sp.

Plate IX, figures 9, 14-16

DESCRIPTION: Aquila pollen, heteropolar, one pole more flattened and broad, the other generally conical, equatorial protrusions like a triangular frill around the body, equatorial protrusions are pointed at the apices or pointedly rounded, colpi run from the apices of the equatorial protrusion towards each other, sometimes only pore-chamber like structure is made around the apical portion of the equatorial protrusions, exine thick, psilate to punctate, ornamentation reticulate or striate.

SIZE: Polar axis 23-37 microns

From the equatorial protrusions to the polar axis 23-37 microns

FIGURED SPECIMEN:

Plate IX,	figure 9	Sc 1-24/1	50.8/125.3
	figure 14	Sc 1-24/1	42.9/129.3
	figure 15	Sc 1-24/1	43.8/108.3
	figure 16	Sc 1-24/1	17.5/129.1

Aquilapollenites sp.

Plate X, figures 2, 3

DESCRIPTION: Aquila like pollen, isopolar, polar protrusions are rounded giving oval shape to the grain in equatorial view, equatorial protrusions are also small around the equator, three pairs of demicolpi at either sides of the equatorial protrusions are very conspicuous, exine psilate and thin.

SIZE: 18.2 by 18.2 microns

FIGURED SPECIMEN:

Plate X,	figure 2	Sc 1-24/1	59.2/122.8
	figure 3	same as figure 2	

Aquilapollenites sp.

Plate X, figures 4,5, 7

DESCRIPTION: Isopolar, polar protrusions not conspicuous, equatorial protrusions have a triangular shape in the equatorial contour, the tips of the equatorial protrusions have thinner exine and it bulges and protrudes out, sometimes crumpled and sometimes takes the shape of a hook-like structure. Colpi long, reaching polar axis running from the apices of the equatorial protrusions, exine scabrate, ornamentation striate.

SIZE: 31.2 to 44 microns

FIGURED SPECIMEN:

Plate X,	figure 4	Sc 1-24/1	48.4/110.0
	figure 5	same as for figure 4	
	figure 7	Sc 1-24/3	53.2/119.6

Aquilapollenites sp.

Plate X, figures 1, 6, 8-10

DESCRIPTION: Pollen grains are similar to the forms described above, but differ in having very short furrow structure, exine scabrate, ornamentation striate.

SIZE: 31.2 to 44 microns

FIGURED SPECIMEN:

Plate X,	figure 1	Sc 1-24/1	43.2/127.6
	figure 6	same as figure 1	
	figure 8	Sc 1-24/1	51.7/124.0
	figure 9	same as figure 8	
	figure 10	same as figure 1	

Aquilapollenites sp.

Plate X, figures 11-14

DESCRIPTION: Aquila like pollen, isopolar, polar protrusions not very conspicuous, equatorial contour triangular with concave sides, apical ends of the equatorial protrusions conical, sharp and with bluntly rounded ends bearing short colpi, exine clavate, ornamentation striate.

SIZE: 39.0 microns in polar view

FIGURED SPECIMEN:

Plate X,	figure 11	Sc 1-24/1	15.7/111.3
	figure 12	same as figure 11	
	figure 13	Sc 1-24/1	48.6/110.0
	figure 14	same as figure 13	

Pollen cf. genus Orbiculapollis Khlonova

Plate XI, figure 10

DESCRIPTION: Free, isopolar, tricolpate, colpi run from the apices and shortly bifurcate and run closely parallel to the exinous margin equatorially and meet each other, exine smooth and thin.

SIZE: 28.6 microns in polar view.

REMARKS: Khlonova (1962) has grouped pollen referable to genus Orbiculapollis under 'Unica' type which includes pollen of Aquilapollenites and Elytranthe.

Genus Kryshtofoviana Samoilovitch, 1961

1961 Kryshtofoviana vera Samoilovitch in Samoilovitch and Mtchedlishvili, Trudy Vses. Neft. Nauch.-Issled. Geol.-Razv. Inst., Leningrad, vol. 177, p. 233-234, pl. 75, figs. 1a-d, 2, 3a-c (type species).

1961 Kryshtofoviana Samoilovitch in Samoilovitch and Mtchedlishvili, Trudy Vses. Neft. Nauch.-Issled. Geol.-Razv. Inst., Leningrad, vol. 177, p. 232-233.

DIAGNOSIS: Tetraporate, two pores on each surface on the central body, dorso-ventral outline elliptical, equatorial flange well developed. Ornamentation on the central body granulate, spinate, or fimbriate. Cingulum like flange with spines, fimbriae or both.

REMARKS: Stanley (1961) designated new genus Wodehouseia which seems synonym of Kryshtofoviana designated by Samoilovitch (1961). Validity of genus name

is to be considered according to the rules of priority. Till it is not clarified, the species described here are classified under genus Kryshtofoviana Samoilovitch as morphological details are more comparable with the species described under this genus.

Kryshtofoviana aspera Samoilovitch, 1961

Plate XI, figures 8, 11, 13

1961 Kryshtofoviana aspera Samoilovitch, Trudy Vses. Neft. Nauch-Issled. Geol-Razv. Inst., Leningrad, vol. 177, p. 234-235, pl. 75, figs. 4a-c, 5.

1961 Wodehouseia spinata Stanley, Pollen et Spores, vol. 3, no. 1, p. 157-160, pl. 1, figs. 1-12.

DESCRIPTION: Tetraporate, dorsoventral outline of central body elliptical. Well developed flange is present. Exine finely well-defined granulate, granule size about one micron, about 9 to 10 spines present on each surface. Length of spines about 12 microns and average breadth in the middle of spines is two microns at the lateral edges.

Flange semicircular in cross-section, membrane finely foveolate, flange is supported by knobby spines. Thickness of the flange about 10 microns.

Pores four in number, two pores on each surface, sometimes obscure due to the spines shadowing over them, pores are located at about one quarter the total body length of each end, pore outline elliptical to slit-like with length of the pore approximately parallel to breadth of the central body.

SIZE: Size of the body excluding flange 31 by 15 to 21 microns

Size of the body including flange 41 to 44 by 36 to 39 microns

REMARKS: The specimen recorded here have sometimes obscure pores. These seem mostly covered by the spine nearby. Granules are stronger than reported in Wodehouseia spinata by Stanley (1961).

FIGURED SPECIMEN:

Plate XI,	figure 8	Sc 2-C/15	45.7/111.9
	figure 11	same as figure 8	
	figure 13	Sc 2-C/14	27.8/126.6

Kryshtofoviana sp.

Plate XI, figures 12, 15

DESCRIPTION: Tetraporate, dorsoventral outline of the central body elliptical. Well developed flange is present. Exine finely well-defined granulate, granule size about one micron, length of the spines about 15 to 18 microns and the breadth in the middle is 2.0 to 2.5 microns at the lateral edges.

Flange semicircular in cross-section, membrane finely foveolate, flange is supported by knobby spines. Thickness of the flange about 15 to 16 microns. Flange overlaps body, overlap about 12 microns.

Pores four in number, two pores on each surface, pores are quite conspicuous, pores are located at about one quarter the total body length from each end, pore outline elliptical to slit-like with length of the pore approximately parallel to breadth of central body, pore size 5 by 2 microns.

SIZE: Size of the body excluding flange 62.4 by 39.4 microns

Size of the body including the flange 72.8 by 52.0 microns

REMARKS: These specimens are larger than K. vera Samoilovitch which has greatest range of size among the spinate types described by Samoilovitch and Mtchedlishvili (1961). Morphologically the above-described specimens have flanges which overlap about 12 microns along the margins of the body. Granulation on the body is very conspicuous.

FIGURED SPECIMEN:

Plate XI,	figure 12	Sc 2-5/3	37.6/112.8
	figure 15	same as figure 12	

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PLATE I

Edmonton Formation, Scollard, Alberta

Figures 1-3	*Sphagnumsporites antiquasporites* (Wilson and Webster) Pocock
Figures 4, 5	*Sphagnumsporites* sp.
Figures 6, 7	*Sphagnumsporites* sp.
Figures 8-10	*Cyathidites* cf. *C. minor* Couper
Figures 11-13	*Gleicheniidites senonicus* Ross
Figure 14	*Punctatisporites* sp.
Figure 15	*Deltoidospora psilotoma* Rouse
Figure 16	*Deltoidospora hallii* Miner
Figure 17	*Deltoidospora* sp.
Figures 18, 19	*Concavisporites acutus* Pflug
Figure 20	*Osmundacidites wellmanii* Couper

All specimens are illustrated at a magnification of X 500 unless otherwise stated.

PLATE I

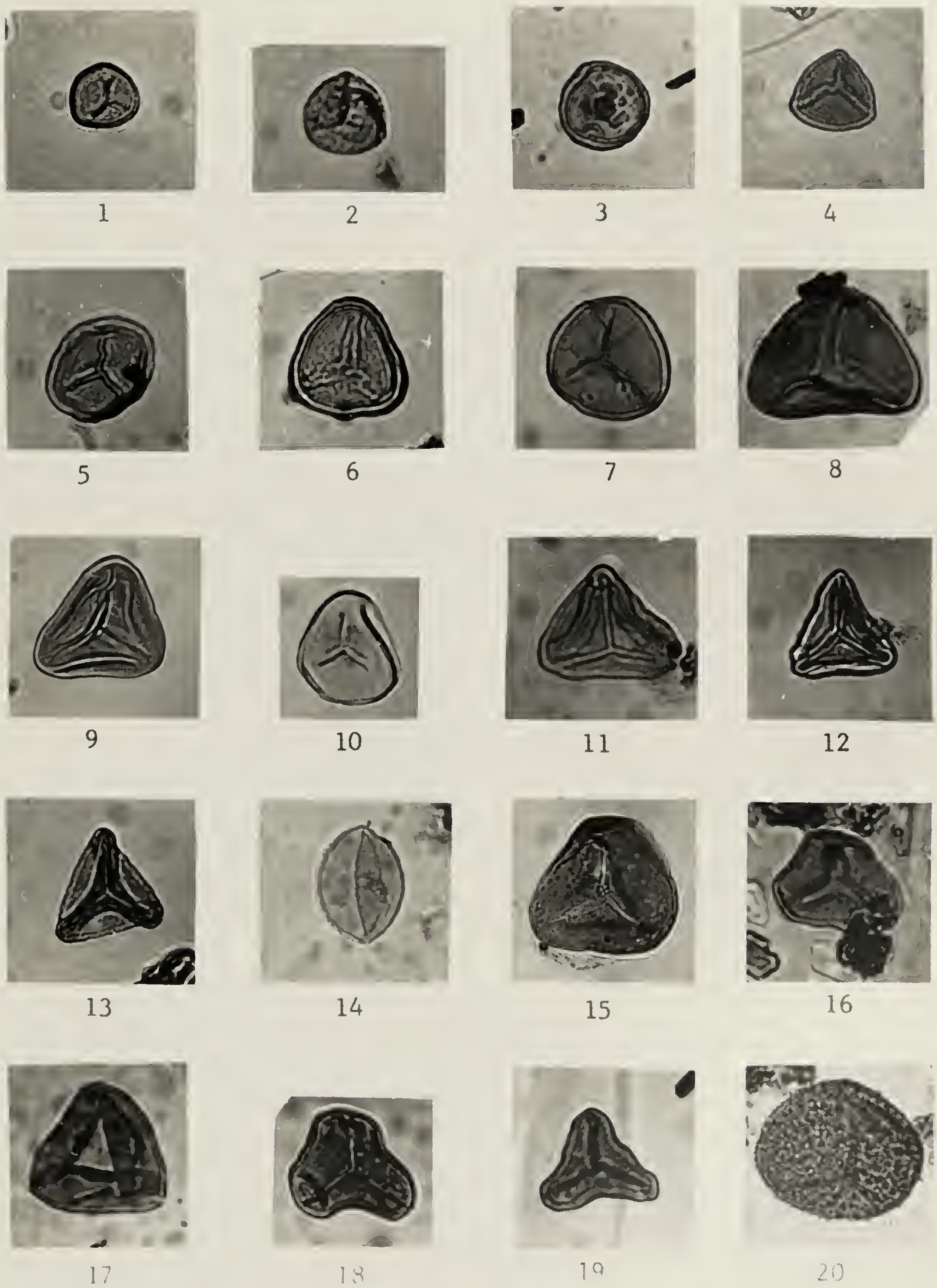

PLATE II

Edmonton Formation, Scollard, Alberta

Figure 1	*Osmundacidites wellmanii* Couper
Figures 2, 3	*Osmundacidites elongatus* (Rouse) new combination
Figure 4	*Lycopodiumsporites vermiculaesporites* (Rouse) new combination.
Figure 5	*Ceratosporites* sp.
Figures 6-8	*Lycopodiumsporites papillaesporites* (Rouse) new combination.
Figures 9-12	*Lycopodiumsporites* sp.
Figure 13	*Baculatisporites* sp. cf. *B. comaumensis* (Cookson) Potonie 1956.

All specimens are illustrated at a magnification of X 500 unless otherwise stated.

PLATE II

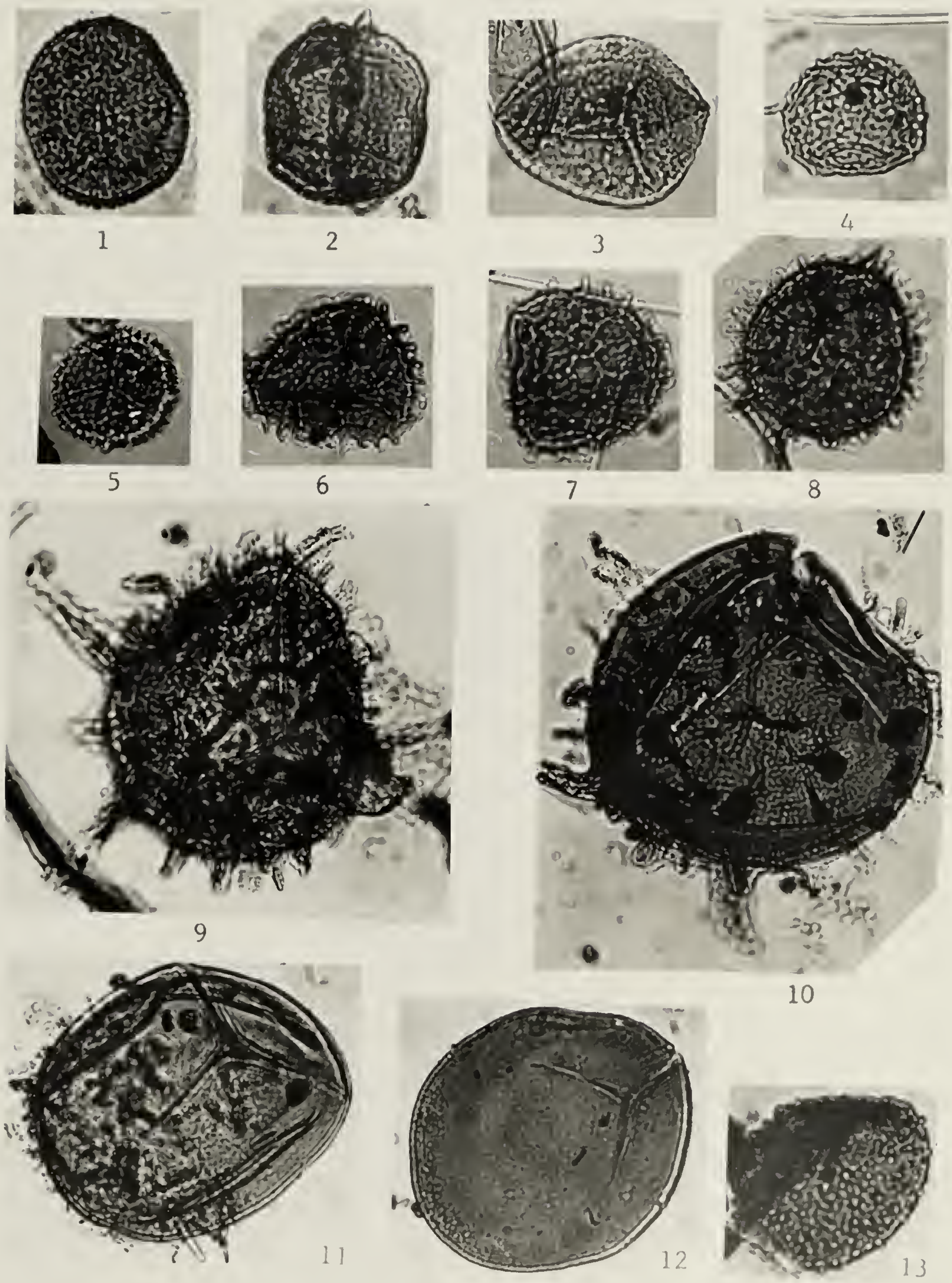

PLATE III

Edmonton Formation, Scollard, Alberta

Figure 1	*Microreticulatisporites* sp.
Figure 2	*Lygodioisporites* sp.
Figures 3-5	*Verrucosisporites asymmetricus* (Cookson and Dettman) Pocock
Figure 6	*Pilosisporites* sp.
Figure 7	*Acanthotriletes* sp.
Figure 8	*Undulatisporites* sp.
Figure 9	*Staplinisporites* sp.
Figure 10	*Triplanosporites* sp.
Figure 11	*Camarozonosporites* sp.
Figure 12	*Azolla* sp. cf. *A. primaeva* (Penhallow) Arnold
Figure 13	A massula of *Azolla* with a microspore in it
Figure 14	Showing many glochidia on the massula wall of *Azolla*
Figure 15	A glochidium of *Azolla* magnified 1,250 X
Figure 16	*Laevigatosporites albertensis* Rouse
Figure 17	*Laevigatosporites discordatus* Pflug in Thomson and Pflug

All specimens are illustrated at a magnification of X 500 unless otherwise stated.

PLATE III

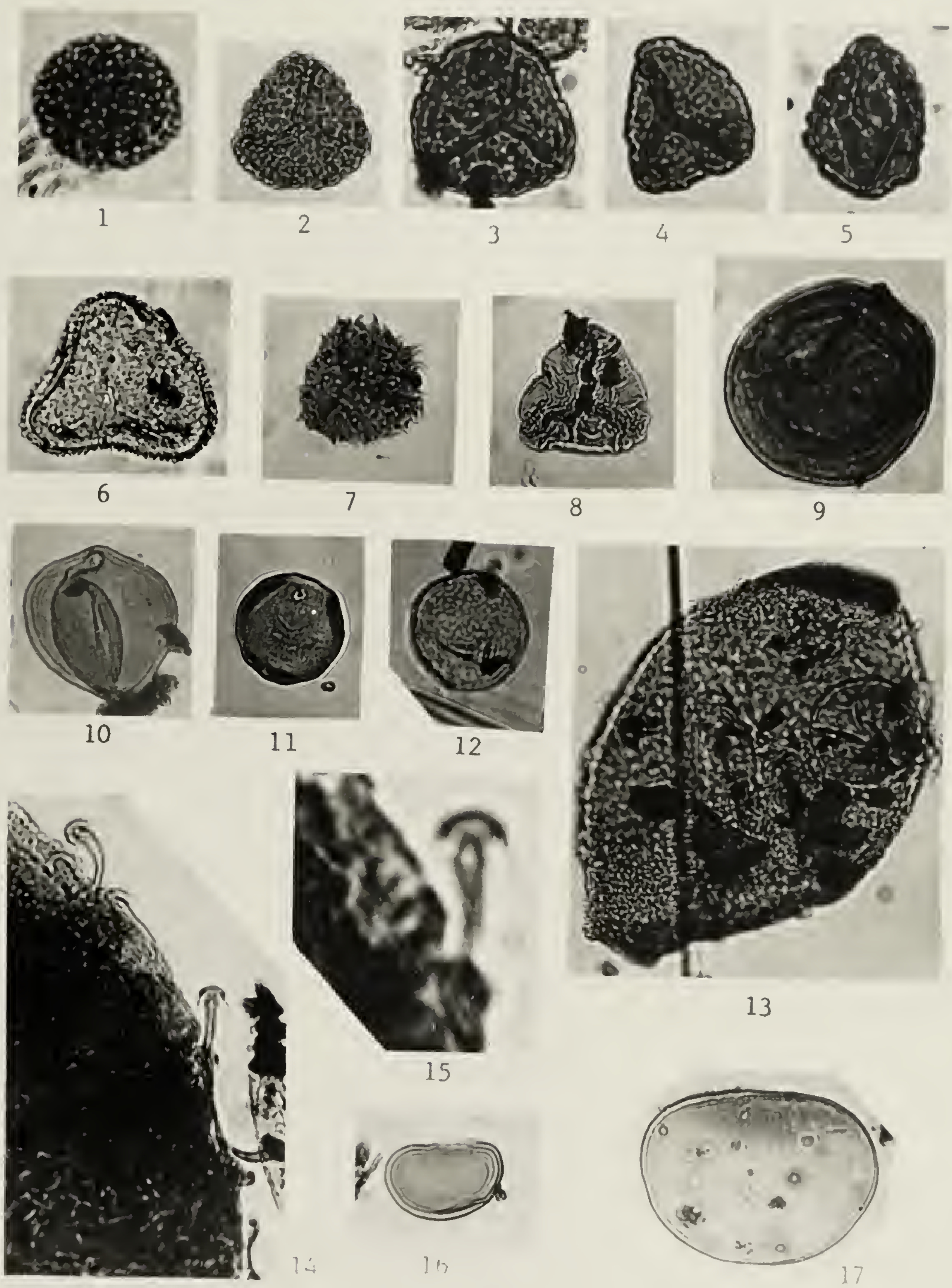

PLATE IV

Edmonton Formation, Scollard, Alberta

Figure 1	*Laevigatosporites discordatus* Pflug in Thomson and Pflug, 1953.
Figure 2	*Laevigatosporites* sp.
Figures 3, 4	*Laevigatosporites ovatus* Wilson and Webster
Figures 5, 6	*Laevigatosporites* sp.
Figure 7	Monoletes sp.
Figures 8, 10	*Polypodiidites perverrucatus* Couper
Figures 9, 11	*Polypodiidites* sp.
Figure 12	Tetrad of spores
Figure 13	*Schizosporis* cf. *S. parvus* Cookson and Dettmann
Figure 14	*Monosulcites* sp.
Figures 15, 16	*Monosulcites* sp.; Figure 15 is under higher magnification of 1,250 X
Figures 17, 18	*Schizosporis* sp. cf. *S. rugulatus* Cookson and Dettmann
Figure 19	*Monosulcites* sp.

All specimens are illustrated at a magnification of X 500 unless otherwise stated.

PLATE IV

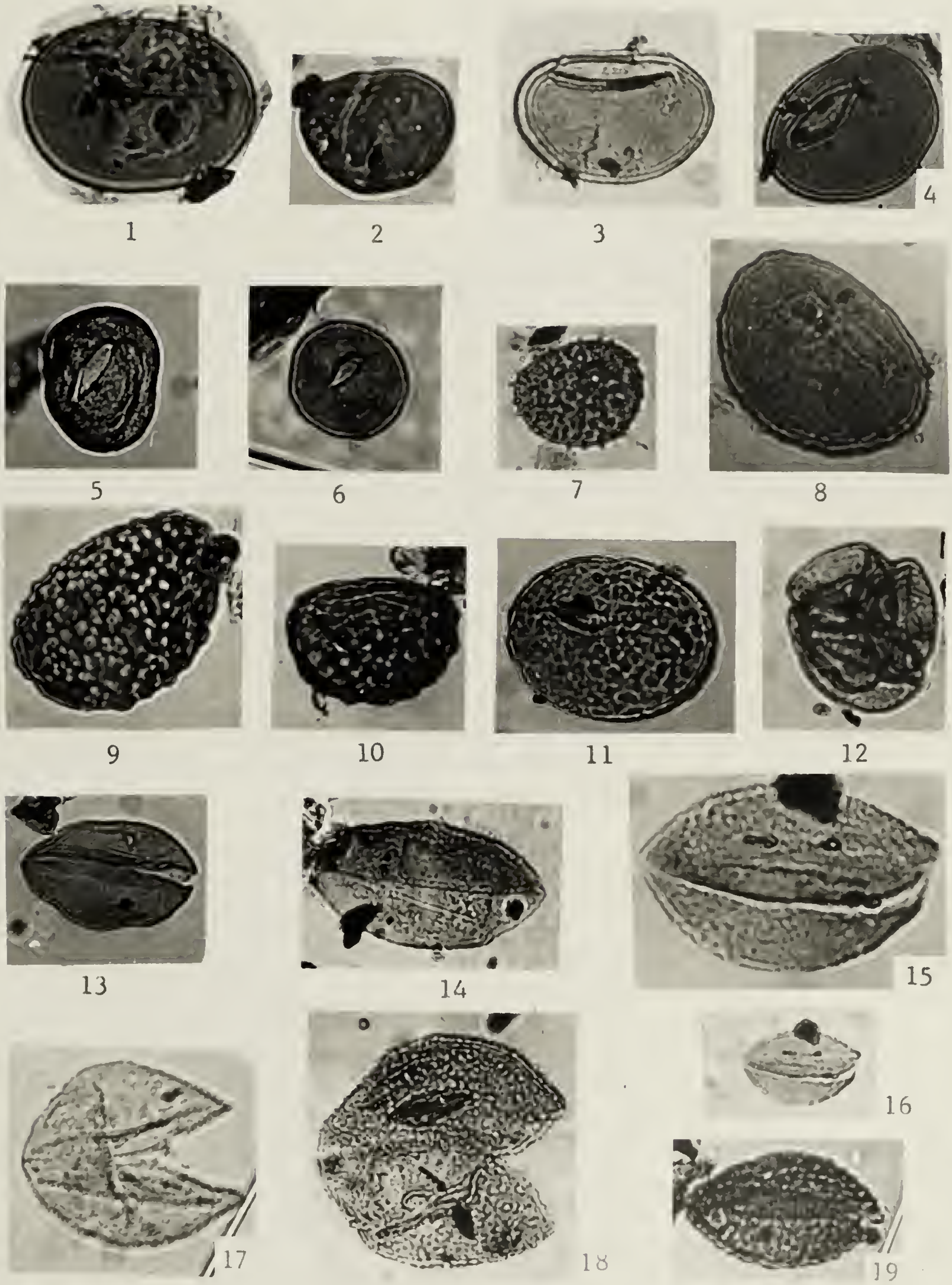

PLATE V

Edmonton Formation, Scollard, Alberta

Figure 1	*Monosulcites* sp.
Figure 2	*Cycadopites* sp.
Figure 3	*Cycadopites* sp.
Figure 4	*Cycadopites* sp.
Figures 5-7	*Cycadopites follicularis* Wilson and Webster
Figures 8, 9	*Taxodiaceaepollenites hiatipites* (Wodehouse) new combination
Figure 10	*Sequoiapollenites* sp.
Figures 11-14	*Inaperturopollenites dubius* (Potonie and Venitz) Thomson and Pflug
Figure 15	*Inaperturopollenites* sp.
Figures 16-19	*Podocarpidites* sp.

All specimens are illustrated at a magnification of X 500 unless otherwise stated.

PLATE V

PLATE VI

Edmonton Formation, Scollard, Alberta

Figure 1	Podocarpidites sp.
Figure 2	Pityosporites sp.
Figure 3	Phyllocladidites sp.
Figure 4	Podocarpidites sp.
Figure 6	Phyllocladidites sp.
Figures 5, 7-10	Cedripites sp.

All specimens are illustrated at a magnification of X 500 unless otherwise stated.

PLATE VI

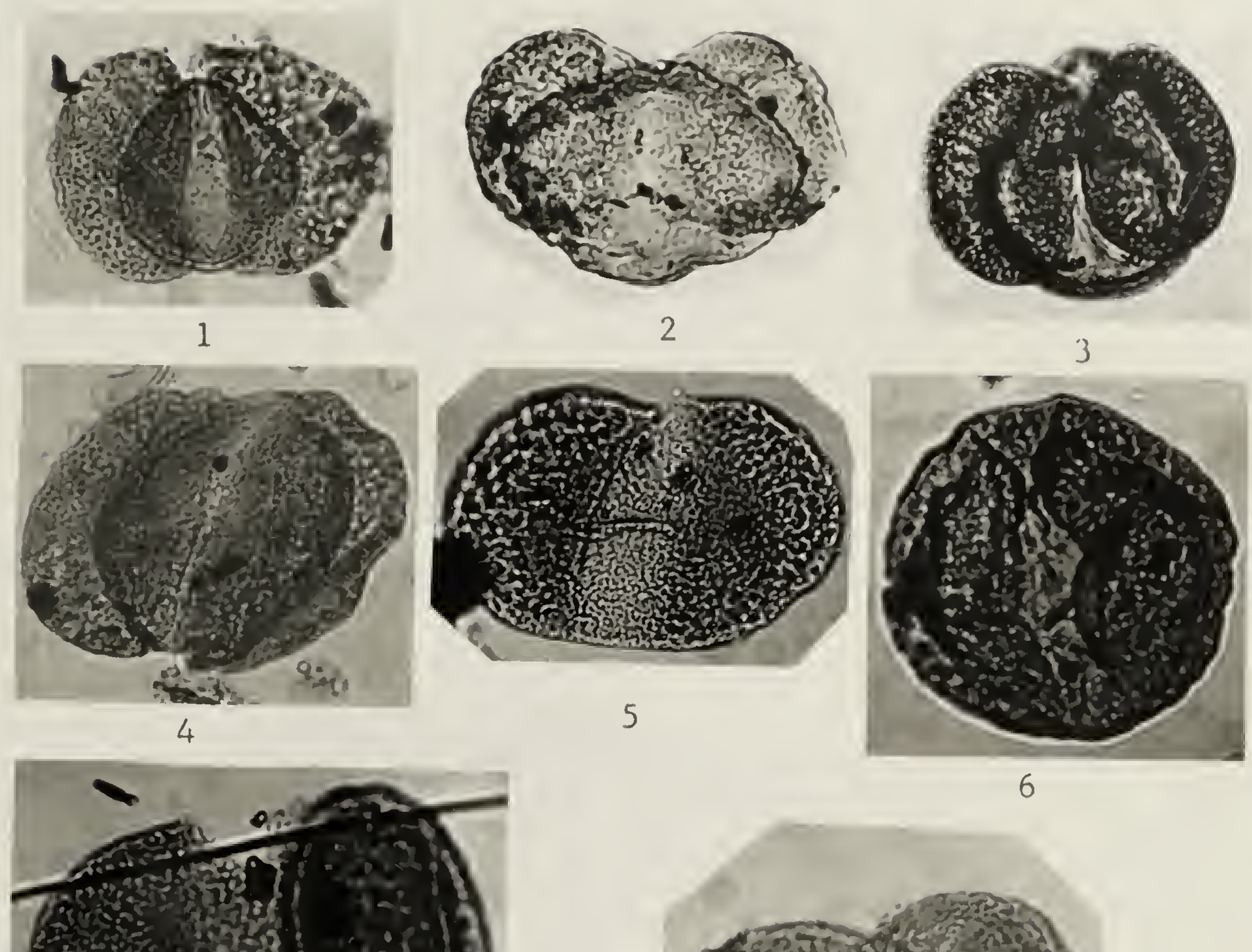

PLATE VII

Edmonton Formation, Scollard, Alberta

Figures 1, 2	*Momipites coryloides* Wodehouse
Figure 3	*Alnipollenites quadrapollenites* (Rouse) new combination
Figures 4-6	*Myricipites dubius* Wodehouse
Figure 7	*Proteacidites* sp.
Figures 8-11	Pollen cf. family Rhizophoraceae
Figure 12	*Rhoipites bradleyi* Wodehouse
Figures 13, 15	Polen cf. *Salix*
Figure 14	Pollen cf. *Ilex*
Figure 16	*Fraxinoipollenites* sp.
Figures 17-19	*Tricolpites* sp.
Figure 20	*Myrtaceidites* sp.
Figure 21	*Myrtaceidites* sp.
Figures 22, 23	*Quercoidites* sp.
Figures 24, 25	*Tricolpites* sp.; figure 25 is of the cluster of *Tricolpites* pollen along with anther remains
Figure 26	*Tricolpites* sp.
Figure 27	*Tetracolpites* sp.
Figures 28-30	*Polycolpites* sp.
Figure 31	*Polycolpites* sp.

All specimens are illustrated at a magnification of X 500 unless otherwise stated.

PLATE VII

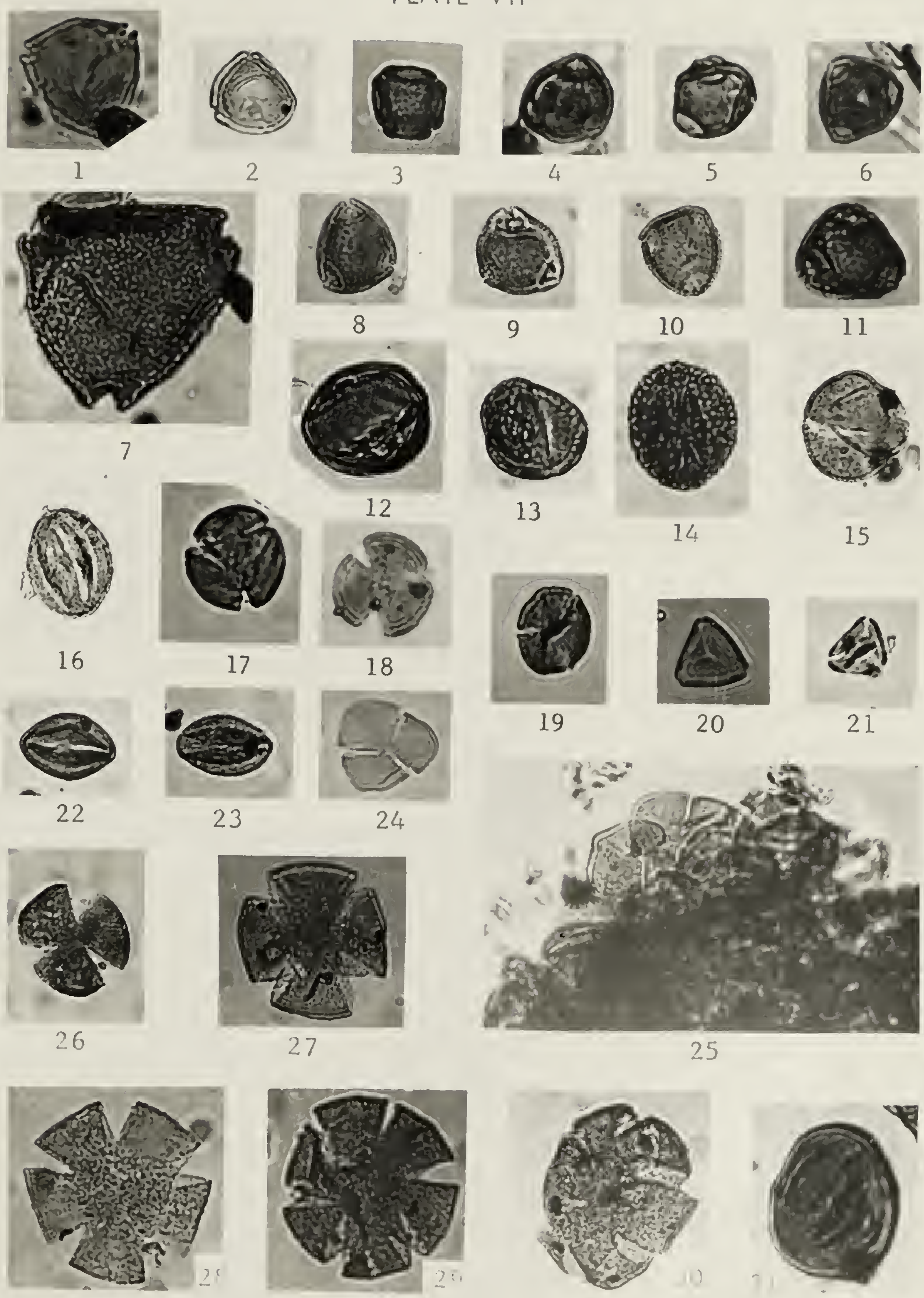

PLATE VIII

Edmonton Formation, Scollard, Alberta

Figure 1 — *Juglanspollenites* sp.

Figures 2-4 — *Ericipites* sp.

Figure 5 — Pollen cf. *Liriodendron psilopites* Wodehouse

Figure 6 — *Liliacidites* sp.

Figures 7-9 — *Liliacidites* sp.

Figures 10-12 — *Aquilapollenites subtilis* Mtchedlishvili; figure 10 - smaller pole of the body shown magnified 1,250 X; figure 11 - one lobe on the equatorial plane of the body along with the furrow region is shown under 1,250 X magnification.

Figures 13-15, 20 — *Aquilapollenites pulcher* Funkhouser; figure 20 under 1,250 X magnification.

Figures 16, 17 — *Aquilapollenites spinulosus* Funkhouser; Figure 16 - pollen shown under 1,250 X magnification.

Figures 18, 19 — *Aquilapollenites* sp.

All specimens are illustrated at a magnification of X 500 unless otherwise stated.

PLATE VIII

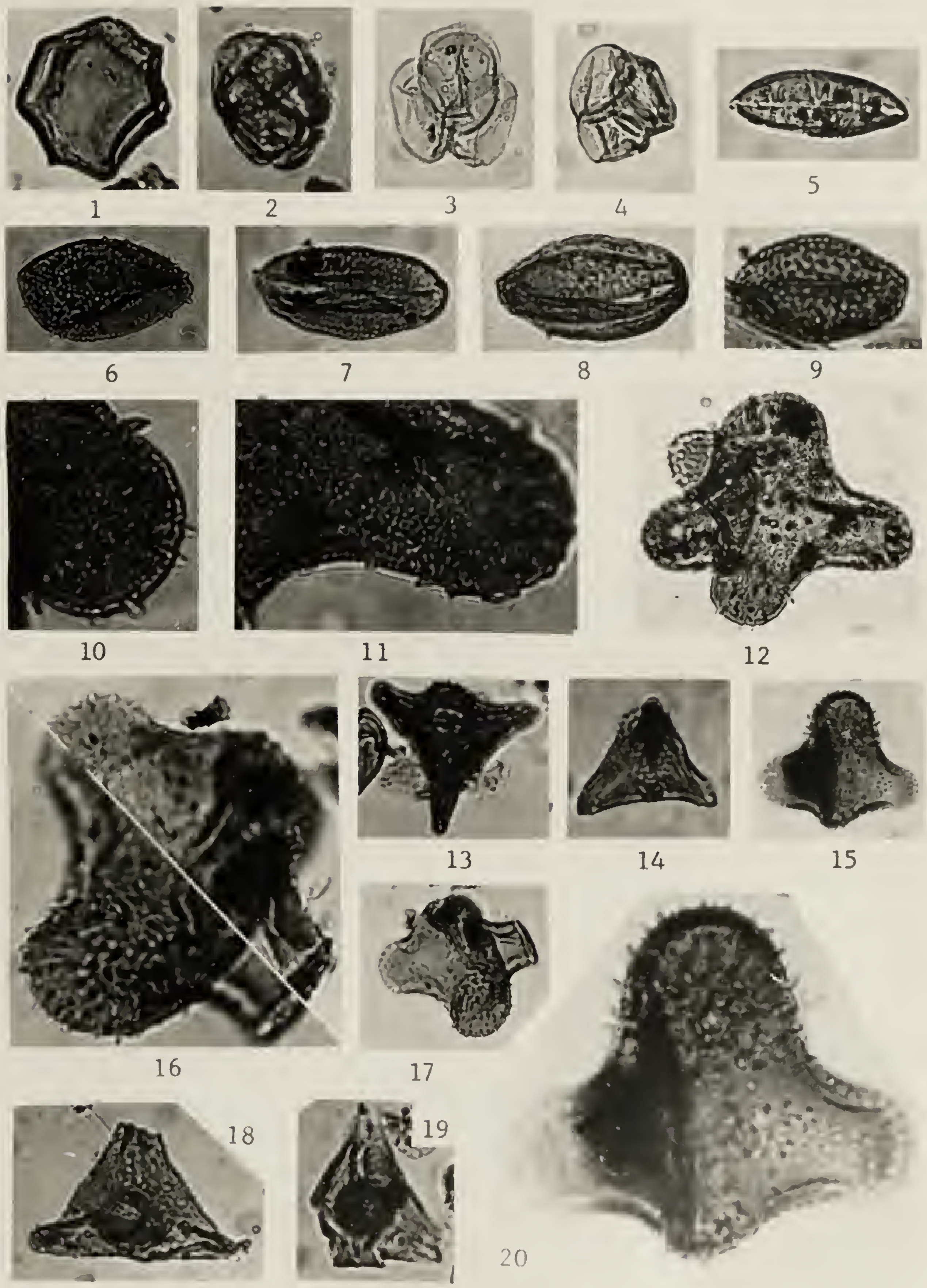

PLATE IX

Edmonton Formation, Scollard, Alberta

Figures 1, 2 — *Aquilapollenites* sp.

Figures 3, 4 — *Aquilapollenites* sp.

Figures 5-8, 10 — *Aquilapollenites* sp.; figures 5 and 6 under higher magnification in different foci to show the exine pattern (1,250 X); figure 7 - same pollen under X 500 magnification; figure 8 - showing the equatorial protuberances and position of the demicolpi (1,250 X); figure 10 - same under normal magnification of X 500.

Figures 11-13 — *Aquilapollenites* sp.; figure 11 - magnification 1,250 X showing exine ornamentation.

Figures 9, 14-16 — *Aquilapollenites* sp.

All specimens are illustrated at a magnification of X 500 unless otherwise stated.

PLATE IX

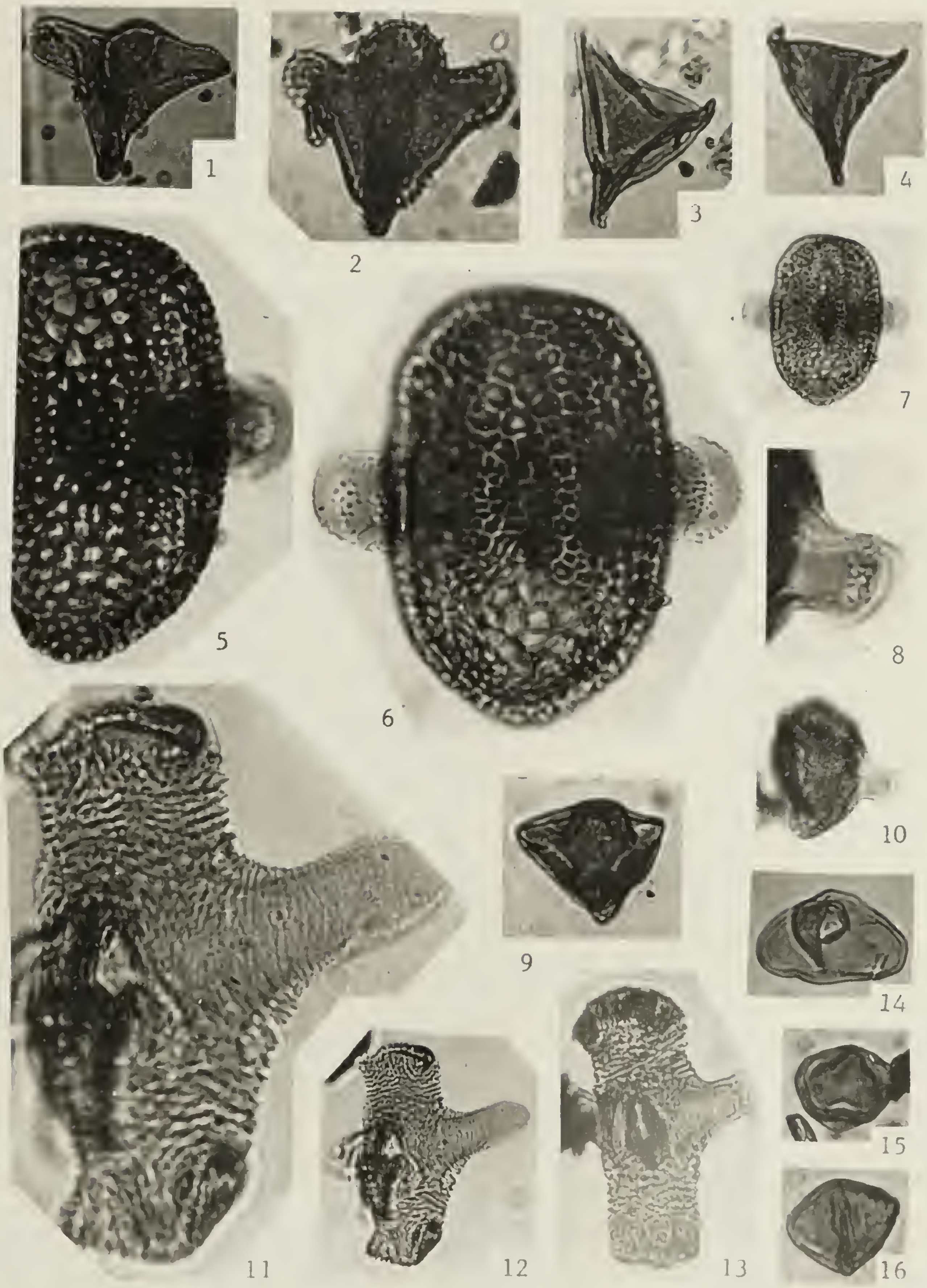

PLATE X

Edmonton Formation, Scollard, Alberta

Figures 1, 6, 8-10	*Aquilapollenites* sp.; figures 1 and 6 are under higher magnification in different foci to show the exine ornamentation (1,250 X); figure 9 is the higher magnification (1,250 X) of the equatorial view of the grain shown in figure 8.
Figures 2, 3	*Aquilapollenites* sp.; figure 2 - magnification 1,250 X.
Figures 4, 5, 7	*Aquilapollenites* sp.; figure 4 shows exine ornamentation under the magnification of 1,250 X.
Figures 11-14	*Aquilapollenites* sp.; figure 11 and 14 show the exine ornamentation under the magnification of 1,250 X.

All specimens are illustrated at a magnification of X 500 unless otherwise stated.

PLATE X

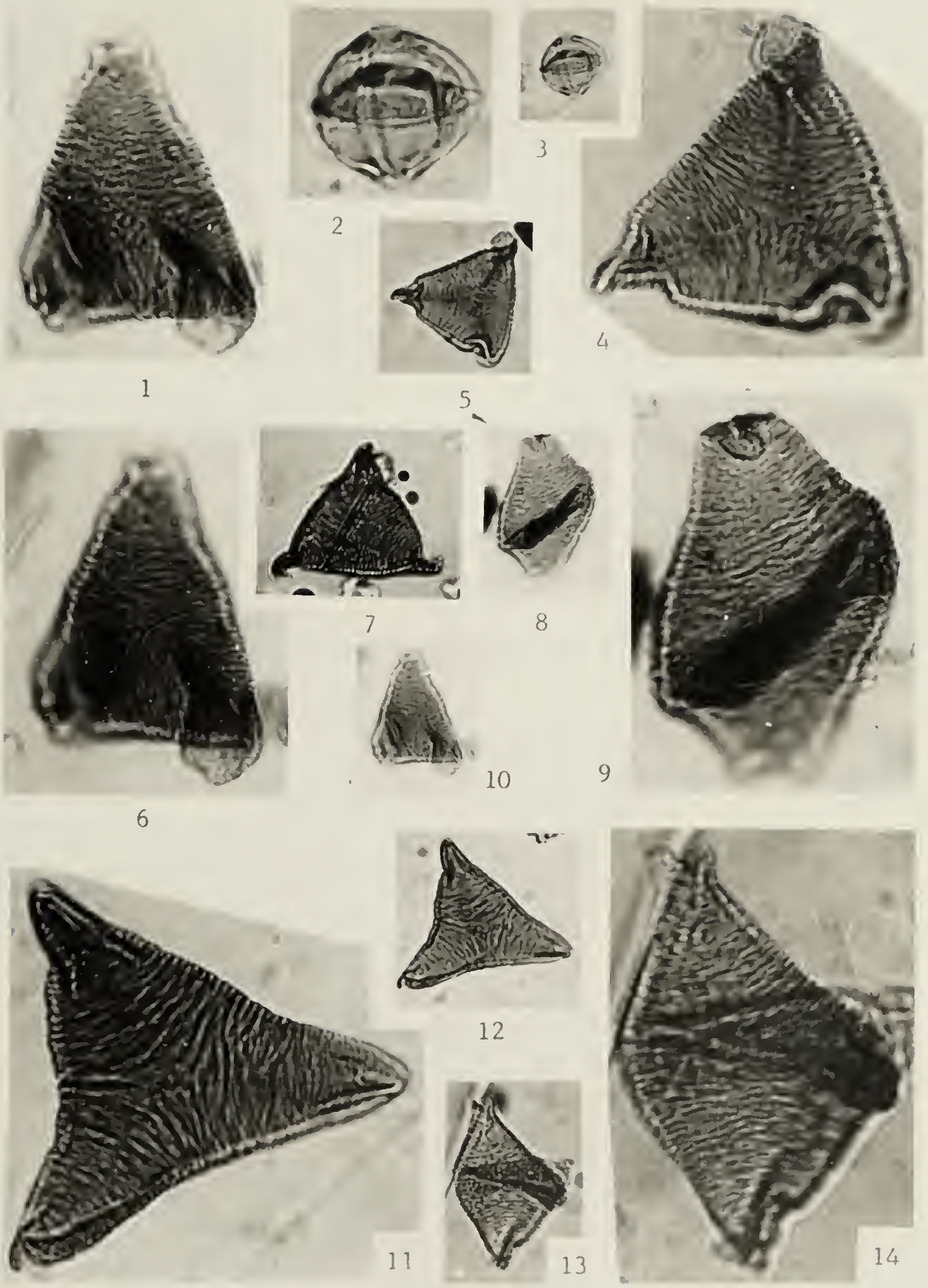

PLATE XI

Edmonton Formation, Scollard, Alberta

Figures 1-7	Elytranthe sp. cf. E. striatus Couper; figures 1, 2 and 3 are magnified X 1,250 of grains shown in figures 4, 6 and 7 respectively.
Figure 9	Elytranthe sp.
Figure 10	cf. Orbiculapollis Khlonova
Figures 8, 11, 13	Kryshtofoviana aspera Samoilovitch; figure 11 shows exine ornamentation in higher magnification X 1,250.
Figures 12, 15	Kryshtofoviana sp.; figure 15 shows exine ornamentation under the magnification of 1,250 X.
Figure 14	Pollen cf. family Restionaceae.

All specimens are illustrated at a magnification of X 500 unless otherwise stated.

PLATE XI

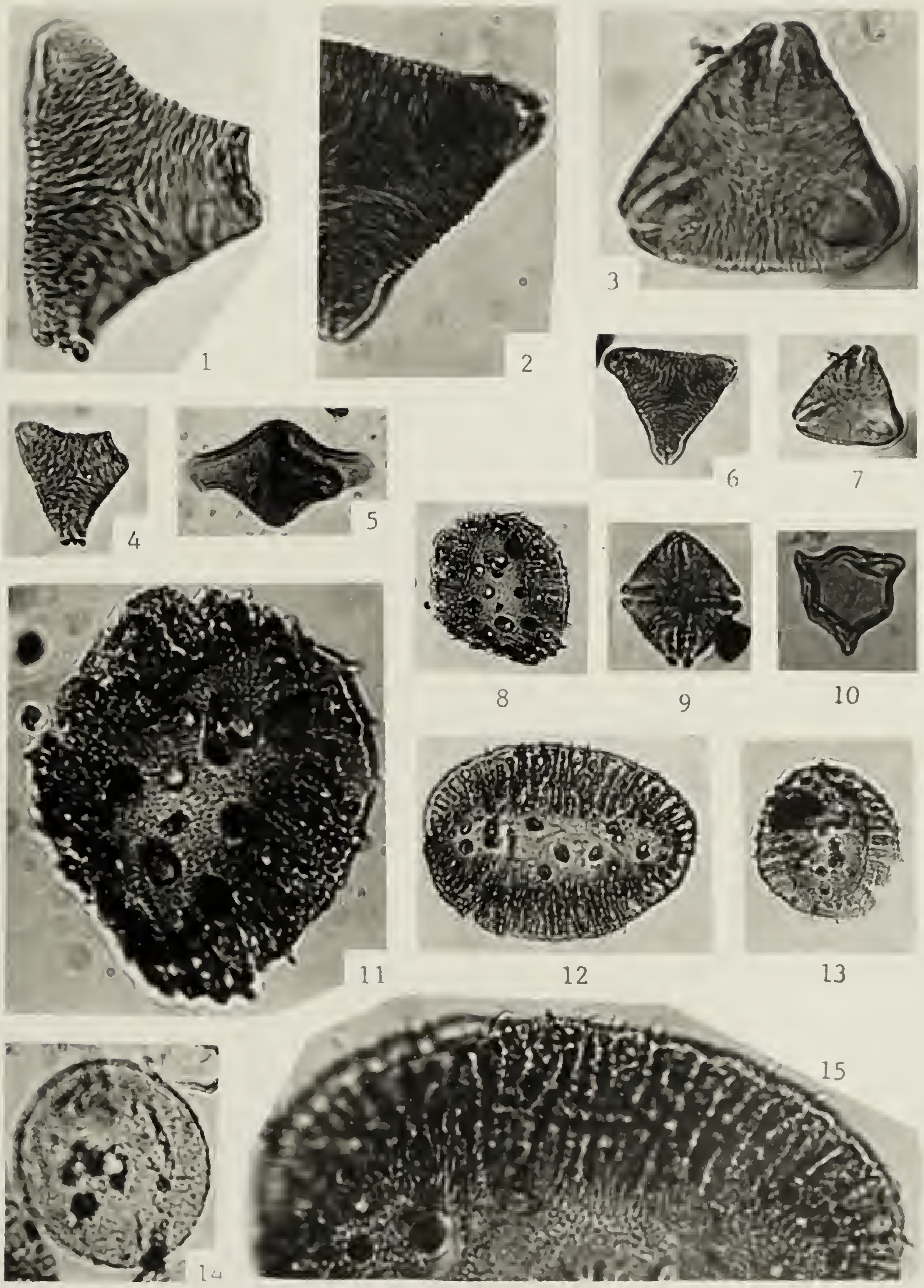

PLATE XII

Figure 1	Upper and Middle Edmonton Formation. Red Deer River Valley, west of Scollard. Blackmud beds capping buttes in middle foreground, with Whitemud beds immediately subjacent.
Figure 2	Middle Edmonton Formation in foreground. Same locality as above.

PLATE XII

PLATE XIII

Figure 1	Mammal Locality No. 1, Upper Edmonton Formation, west of Scollard. Actual quarry marked by X.
Figure 2	Kneehills Tuff in foreground, Upper Edmonton Formation in background near Mammal Locality No. 1, west of Scollard. Dark band in upper left corner is the Ardley coal seam.


1


2

PLATE XIV

Aerial photograph of the area west of Scollard, showing localities for Palynology Samples, Scollard Localities 1, 2 and 18. The arrows point to the collecting quarries.


18
2
1

B29839